British phenological records indicate high diversity and extinction rates among late-summer-flying pollinators

Article (Accepted Version)

British phenological records indicate high diversity and extinction rates among late-summer-flying pollinators

Nicholas J. Balfour1, Jeff Ollerton2, Maria Clara Castellanos1 and Francis L.W. Ratnieks1

1 School of Life Sciences, University of Sussex, Brighton, BN1 9QG, United Kingdom

2 Faculty of Arts, Science and Technology, University of Northampton, Avenue Campus, Northampton, NN2 6JD, UK

Corresponding author: Nicholas J. Balfour; njbalfour@gmail.com, Telephone: +44 (0)1273 872954; Fax: +44 (0)1273 678335

Abstract

The long-term decline of wild and managed insect pollinators is a threat to both agricultural output and biodiversity, and has been linked to decreasing floral resources. Further insight into the temporal relationships of pollinators and their flowering partners is required to inform conservation efforts. Here we examined the phenology of British: (i) pollinator activity; (ii) insect-pollinated plant flowering; and (iii) extinct and endangered pollinator and plant species. Over 1 million records were collated from the historical databases of three British insect monitoring organisations, a global biodiversity database and an authoritative text covering the national flora. Almost two-thirds (62%) of pollinator species have peak flight observations during late-summer (July and August). This was the case across three of the groups studied: aculeate wasps (71% of species), bees (60%), and butterflies (72%), the exception being hoverflies (49%). When species geographical range (a proxy for abundance) was accounted for, a clear late-summer peak was clear across all groups. By contrast, there is marked temporal partitioning in the flowering of the major plant groups: insect-pollinated tree species blossoming predominantly during May (74%), shrubs in June (69%), and herbs in July (83%). There was a positive correlation between the number of pollinator species on the wing and the richness of both flowering insect-pollinated herbs and trees/shrubs species, per calendar month. In addition, significantly greater extinctions occurred in late-summer-flying pollinator species than expected (83% of extinct species vs. 62% of all species). This trend was driven primarily by bee extinctions (80% vs. 60%) and was not apparent in other groups. We contend that this is principally due to declines in late-summer resource supplies, which are almost entirely provisioned by herbs, a consequence of historical land-use change. We hypothesize that the seasonality of interspecific competition and the blooming of trees and mass-flowering crops may have partially buffered spring-flying pollinators from the impacts of historical change.

Keywords: Endangered species, Extinctions, Flowers, Flower visitors, Foraging resources, Phenology, Pollinators, Seasonality.

Introduction

The contribution of insect pollinators to maintaining global biodiversity and agricultural output is well established (88% of flowering plant species and 35% of crop species; Ollerton et al., 2011; Klein et al., 2007). However, there are ongoing concerns regarding the long-term decline of both wild and managed pollinators in North America and Europe (e.g. Goulson et al., 2015; Hallaman et al., 2017; Ogilvie et al., 2017). While many potential causes have been identified, decreasing floral resources (chiefly nectar and pollen) are considered to be a key factor (e.g. Carvell et al., 2006; Potts et al., 2010; Scheper et al., 2011; Goulson et al., 2015).

Thus, a better understanding of the temporal relationship between the supply of, and demand by pollinators for, floral resources is required. The majority of research in this area has focused on single communities or the potential for climate change to disrupt plant-pollinator mutualisms (e.g. Abu-Asab et., 2001; Willis et al., 2008; Aldridge et al., 2011). Regional analyses are rare (Burkle et al., 2013; Ollerton et al., 2014) and no study, to our knowledge, has ever quantified the phenological relationship between pollinators and floral resources throughout the year at a regional level. Further insights into the seasonal relationships of these mutually reliant groups are important to understanding pollinator ecology and developing the temporal elements required for optimal conservation strategies (Kearns et al., 1998).

Floral declines have been attributed to changes in British agriculture during the last century (reviewed in Robinson and Sutherland, 2002). These include a reduction in unimproved grasslands (Fuller, 1987), haymeadows (reviewed in Jefferson, 2005) and hedgerows (Robinson and Sutherland, 2002), combined with an increased use of herbicides (Whitehead & Wright 1989) and artificial fertilizers (Ollerton et al., 2014).

Floral resource scarcity, particularly of nectar, has most commonly, if not exclusively, been reported during late-summer (July and August) in both Europe (e.g. Von Frisch, 1967; Lack, 1982; Williams 1998; Thomson, 2006; Williams 1998; Scheper et al., 2014; Couvillon et al., 2014a; 2014b; Holland et al., 2015; Balfour et al. 2015a) and North America (e.g. Inouye, 1978; Weatherwax, 1986: Pope and Jha, 2018). However, recent research indicates that, across the British landscape, the majority of nectar is produced during these months (60%; Baude et al., 2016). These seemingly conflicting results raise several questions regarding late-summer nectar resource depressions: (i) are they a natural phenomenon caused by a mismatch between seasonal floral resource supply and demand by pollinators? and/or (ii) are they a consequence of long-term anthropogenic environmental changes?

Here, we begin to address these questions by examining the annual phenology of British pollinator flight and the flowering of insect-pollinated plants, with a particular focus on late-summer. This information was collated from an authoritative text covering the national flora, the historical records of three UK insect monitoring organisations and a global biodiversity database. Furthermore, to ascertain whether late-summer pollinator communities have been disproportionally impacted by anthropogenic environmental change we assessed the phenology of extinct and endangered UK pollinator and plant species.

Methods

Pollinator Species Phenology

Phenological data for the four main groups of flower visitors in Britain (aculeate wasps, bees, butterflies and hoverflies) were collated from the historical records of the Bees, Wasps and Ants Recording Society (BWARS), the UK Butterfly Monitoring Scheme (UKBMS) and the Hoverfly Recording Scheme (HRS) databases. We used all records in these databases, with the exception of those that contained: (i) species listed as *sensu lato* (i.e. only *sensu stricto* records were used); (ii) species aggregates (i.e. a species group composed of closely related

86 species that are difficult to distinguish); (iii) species names we identified as defunct
87 (synonymies records were used for the relevant species); (iv) species named '*binomial* Form
88 A' or '*binomial* species B' (HRS); and (v) dates recorded as Christmas or New Year's Day
89 (December 25 or January 1 are commonly used for an unknown day and month, but known
90 year).

91 Initially, nationwide records from all years were grouped per month and per species.
92 For data-deficient pollinator species (<50 total observations; n = 87 species, 11% of all
93 species analysed) we incorporated additional data from the Global Biodiversity Information
94 Facility (GBIF) database. A total of 8,517 GBIF records (24% of the total observations for
95 these 87 species) were taken from an area of North Eastern Europe (Appendix S6) with a
96 similar phenology as Britain (Moulin et al. 1997). The remaining species with <50 total
97 observations were excluded from analysis.

98 We then calculated the flight period of each pollinator species, which was defined as
99 all calendar months with ≥10% records (per species) in the relevant database(s). To avoid
100 underestimating the flight period of infrequently recorded species a percentage was used,
101 rather than a minimum number of records, in this calculation. To provide greater resolution
102 on pollinator phenology we also calculated the month(s) with the greatest number of
103 observations for each species (Fig. 1a). Because some pollinators have multiple generations
104 in a year (e.g. *Andrena flavipes*) and others a protracted flight period (*Eumenes coarctatus*),
105 many species had approximately equal and maximal observations in more than one month.
106 Therefore, when the difference between the two months with the greatest number of
107 observations was ≤10%, the peak abundance of that species was considered to be spread
108 across both months (e.g. *Bombus lapidarius* observations are equal and maximal in July and
109 August, resulting in both months being scored 0.5 for this species). When the difference was
110 >10% the abundance of a species was considered to peak in only one month (e.g. *Bombus*

111 *pratorum* peak observations are in June, resulting in this month being scored 1 for this
112 species).
113 Overall, our analysis included: 87% of aculeate wasp (248/284), 98% of bee
114 (247/253), 100% of butterfly (64/64) and 92 % of hoverfly (261/284) species listed in their
115 respective databases (Appendices S1-S4).
116 *Insect-Pollinated Plant Species Phenology*
117 A comprehensive dataset of the peak flowering month(s) of British species could not
118 be identified. Therefore, the complete flowering periods of British plant species were taken
119 from Clapham et al., (1990). A list of the British insect-pollinated plant species was
120 generated using the Ecological Flora Database (Fitter and Peat, 1994), which combines data
121 from a variety of sources. The Royal Horticultural Society classification (Brickell, 2010) was
122 used to group plant species into herb (non-woody), shrub (<5m) or tree (>5 m). We then
123 calculated the months that insect-pollinated plant species are in flower (Fig. 1b and Fig. 2).
124 Overall, our analysis included: 776 herb, 45 shrub and 38 tree species.
125 *Pollinator and Plant Species Distribution*
126 To ascertain whether our phenology calculations were representative of the total number of
127 active pollinators and blooming insect-pollinated plants per month we accounted for the
128 relative abundance of each of pollinator and plant species. This was achieved by using
129 geographical distribution as a proximate measure of the local abundance of each species (e.g.
130 Brown 1984; Gaston et al., 1997). Geographical distributions of aculeate wasp, bee and
131 hoverfly species' were determined by calculating the number of unique hectads (10 km × 10
132 km square) in which they had been recorded (BWARS and HRS databases). Butterfly
133 species' distributions were taken from the UKBMS Butterflies for the New Millennium
134 survey (UKBMS, 2017). Insect-pollinated plant distributions were taken from Hill et al.
135 (2004). Geographical ranges and phenology data were then combined (Fig. 1c and d) by

multiplying the number of hectads per species by the previously calculated pollinator and flowering plant phenology (e.g. *B. lapidarius* has been recorded in 1188 hectads, therefore both July and August were 'scored' 594). The number of records used to calculate these geographical distributions varied substantially between the four pollinator groups: aculeate wasps (138,000 records), bees (320,000), butterflies (2,970,000) and hoverflies (502,000). No adjustments were made to account for these sampling effort discrepancies, due to the divergent sampling strategies of BWARS, UKBMS and HRS. As such, it is not possible to compare the relative abundance of the pollinator groups. However, this is possible among the three plant groups.

Extinct and Endangered Pollinator and Plant Species Phenology

The list of the extinct, critically-endangered and endangered pollinators was compiled from the most up-to-date source available for each group: aculeate wasps (Falk, 1991; Ollerton et al., 2014), bees (Falk, 1991; Falk, 2015), butterflies (Fox et al., 2011) and hoverflies (Ball et al., 2013). The month(s) with the greatest number of observations per species was calculated using the methodology described previously (Appendix S5). Species that have been driven to extinction by anthropogenic factors and subsequently reintroduced (*Bombus subterraneus* and *Maculinea arion*) were classified as extinct in analysis. To retain all species in our analysis, no lower limit was set for the number of observations required to calculate each species' phenology. The flowering period of extinct, critically endangered and endangered insect-pollinated plant species (Cheffings et al., 2005) was determined using the methodology described previously.

Chi-squared analyses were conducted using ‘R’ software (R-Project, 2017) and compared raw numbers (observed values of extinct and/or endangered species) to the expected probabilities (calculated as the corresponding proportion of all extinct + extant species) from the phenological data in Appendices S1-S5.

Database Accuracy

With over 1 million records among them, the HRS, BWARS and UKBMS databases are probably the most detailed available for any country. Records within each databases are single species-level observations on specific dates. Most of the recordings are made by volunteers and whilst the data may have been collected following a specific protocol, the majority of records in these datasets are opportunistic. Therefore, to account for sampling effort in our butterfly phenology calculations, we calculated the number of observations per species, per transect. This was achieved by dividing the total number of UKBMS observations per month for each species by the total number of fixed-route transects per month. Unfortunately, these data were not available for the BWARS or HRS databases. The mean (± standard error) number of years with ≥10 records per species within each database was: aculeate wasps and bees, 16 ± 0.6 (BWARS, 1740-2015); butterflies, 31 ± 1.1 (UKBMS, 1976-2014); and hoverflies 18 ± 1.1 (HRS, 1824-2013). Because our data are taken from multiple years pollinator flight phenology should not be influenced by extreme years. Although climate change is likely to have shifted pollinator phenology over recent centuries (e.g. Bartomeus et al., 2013), the majority of records in each of the primary databases were collected since 1990: BWARS 70%, UKBMS 74% and HRS 53%. Therefore, the data are largely representative of modern pollinator phenologies.

The GBIF data are taken predominately from museum collections (48%) and national biodiversity recording schemes (45%). To ascertain the accuracy of the GBIF phenology data we compared the peak month(s) of 100 randomly selected species calculated from the European data (GBIF) and the British data (BWARS, UKBMS or HRS), using the methodology described above. There was 80% agreement between the datasets. This was calculated by comparing the peak month(s) generated per species and scoring agreement as:

100% (peak month(s) matched exactly), 50% (e.g. one dataset indicating May and June and the other June and July) or 0% (no agreement databases).

Results

The majority (62%) of British flower visitor species have peak observations in July and August, Fig. 1a. This was also the case for three of the pollinator groups studied (Appendices S1-S4): aculeate wasps (71% of species), bees (60%), and butterflies (72%); but not hoverflies (49%). When each species geographical range (a proxy for abundance) was accounted for, a clear late summer peak was clear across all groups

Bee species richness was found to be lower in June (18% of species) than during May (22%) or July (43%; Fig 1a). When the geographical range is accounted for, the data indicate that hoverfly and butterfly abundances also dip between May and July (Fig 1c). Tree species flower predominantly during spring (74% in May), shrubs in early summer (69% in June), while herbs peak in July (83%), Fig 1b. Accounting for plant species geographical range did not alter this pattern, Fig. 1d.

A significant positive correlation was found between the number of flower-visiting insects on the wing and the richness of insect-pollinated herbs and tree/shrub species in bloom, per calendar month (herbs: $F = 100.5$, $df = 11$, $P = <0.001$; trees and shrubs: $F = 11.6$, $df = 11$, $P = 0.007$; Fig. 2).

We found 40 extinct species of pollinators in the UK spread across three groups: 10 aculate wasps, 25 bees and 5 butterflies; there have been no recorded hoverfly extinctions. Analysis indicates that a greater than expected proportion of extinct pollinators are late-summer-flying (July-August) species (82.5% of extinct species vs. 61.8% of extinct + extant species; $\chi^2 = 7.3$, $df = 1$, $P = 0.007$; Fig. 3a; Appendix S5). Phylogenetic effects are unlikely to drive this result, as the same output is obtained if we limit the analysis to the genera with extinct species. Comparing the phenology of the 40 extinct species with their 190 extant

congeners provides the same statistical output (26 genera; extinct: 82.5% vs. extinct + extant: 54.7%; $\chi 2 = 12.5$, df = 1, P <0.001). This trend was driven primarily by the bee extinctions (80.0% extinct vs. 59.5% extinct + extant; $\chi^2 = 4.4$, df = 1, $P = 0.037$) and was not apparent among aculeate wasps or butterflies ($P>0.05$). Extinct bee species belong to different families with varied life histories, and are not restricted to specialized groups. No late-summer pattern was identified among endangered pollinators or extinct or endangered plants (extinct and endangered plant species were combined for analysis, Fig. 3b).

Discussion

This unique dataset confirms for the first time, at the regional scale and across multiple insect groups, that late-summer (July and August) is the annual peak of pollinator and herb reproduction in the UK, Fig 1. This season is, therefore, crucial to the survival of these mutually reliant groups. Indeed, July and August have previously been noted as the height of bumble bee (Edwards & Williams, 2004), honey bee (Seeley, 1995), social wasp (Spradberry, 1973) and butterfly (Roy et al., 2007) activity. Thus, this period is critical for the reproductive success of most British bumble bees (Goulson, 2003), including rare and declining species (Williams & Osbourne, 2009) and for honey bee colonies to gather winter stores (Seeley, 1995). Hoverflies were the exception to this pattern. The phenology of these Batesian mimics may not necessarily follow that of their models, rather their emergence is considered subject to predator avoidance and the availability of oviposition sites (Walderbauer & LaBerge, 1985; Waldbauer, 1988).

The spring peak of bee species activity is largely due to the phenology of the species-rich genera *Andrena* and its cleptoparasites *Nomada* (67% of bees with peak observations in April and May were of these genera). These months concide with peak tree species flowering (82% of species flower in April and May) and, consequencely, *Andrena* spp. are known to

frequent tree flowers (e.g. *Pyrus*, *Prunus*; Chambers, 1946), at times almost exclusively (e.g. *Salix*; Falk, 2015).

Interestingly, the data also indicate that bee diversity dips between May and July (Fig 1a). This June lull in bee diversity coincides with a gap between peak tree and herb flowering (Fig. 1b) and, therefore, may reflect limited forage availability at this time. This is consistent with the long held belief of British beekeepers in a 'June gap' that is relatively bereft of nectar resources (e.g. Horn et al., 2015). Intrugingly, when pollinator species geographical range (a proxy measure of abundance) is factored in, this pattern is repeated in the phenology of hoverflies and butterflies, but not aculeate wasps, Fig. 1c. These early season patterns indicate that pollinator community phenology is driven by factors beyond just temperature.

We also identified a positive correlation between the number of flower-visiting insects on the wing and the richness of blooming insect-pollinated herb and tree/shrub species (Fig. 2). A seasonal synchrony between the richness of pollinator species and that of flowering plants is perhaps intuitive, and has been described in local North American communities (Mosquin, 1971; Tepedino & Stanton 1981), but has not been quantified previously for the UK.

These findings, therefore, suggest that the supply of floral resources is well matched to demand throughout the year. However, we also found a significantly greater proportion of extinct late-summer-flying pollinator species (83%) than expected (62% of all species). This trend was driven primarily by bee extinctions (80%). From broad trends in the data presented here, and in the scientific literature, we hypothesise that there are two important factors responsible for the disproportionally high extinction rate of late-summer pollinators.

First, floral resources during late-summer (July and August) have markedly declined over the past century and are now likely to be patchily distributed across Britian. Baude et al. (2016) estimated that just four late-summer blooming plant species provisioned over half of

nectar nationally in 2007. However, at least three of these once widespread species have suffered acute long-term declines. Two are heathland species, *Calluna vulgaris* (-36% from 1978-2007 Countryside Surveys, calculations followed those of Carvell et al., 2006) and *Erica cinerea* (-50%, 1978-2007), which have long been casualties of agricultural improvement and afforestation (Thompson et al., 1995). At the same time the use of white clover (*Trifolium repens*) to fix nitrogen in pastureland has waned since the introduction of artificial fertilisers early last century (-52%, 1978-2007). The fourth species, *Cirsium palustre* (-13%, 1978-2007), is a wetland thistle that has also declined due to habitat losses (Dugan, 1990). Additionally, during July-August there is a scarcity of flowering crops in Northern Europe (Scheper et al., 2014) and, as shown here, few blooming trees and shrub species. Thus, wildflowers represent the principal source of nectar and pollen during late-summer. However, agricultural intensification during the second half of the last century (Robinson & Sutherland, 2002), and perhaps earlier (Ollerton et al., 2014), has severely impacted wildflower populations. Currently one-fifth of English wildflower species are classified as 'threatened' and around twenty traditionally widespread species are considered 'near threatened' (Stroh et al., 2014).

Historical declines in late-summer floral resources are likely to have impacted bee species more acutely than other pollinator groups because bee diets are derived almost exclusively from floral sources. By contrast, aculeate wasps, butterflies and hoverflies are either predatory or herbivorous during their larval stage, often carrying reserves over to their adult phase (Romeis et al., 2005). Nevertheless, there is evidence to suggest that hoverfly (Meyer et al., 2011), aculeate wasp (Karem et al., 2010) and butterfly (Kunte, 2008; however, see Thomas et al., 2011) populations are related to floral resource abundance. In general this area remains poorly understood across all groups (Vanbergen et al. 2013; Goulson et al., 2015). It is also noteworthy that the majority of UK pollinator extinctions were pre-1950

(65%) and thus predate widespread agricultural chemical use (i.e. pesticides and artificial fertilizers). Thus, implying longer-term changes such as the end of transhumance (Evans, 1940; the resting of lowland pastures during the summer) and shift from hay making to silage (Fitzpatrick et al., 2007) have also played a role in pollinator extinctions.

Second, we hypothesize that spring-flying pollinators may have been partially buffered from the impact of historical floral declines due to the seasonality of competition and the blooming of trees and mass-flowering crops. This may partly explain why spring-flying species have not suffered the same extinction rate as their summer-flying cousins. The demand for floral resources is likely to be far greater during summer than in spring due to the colony life cycle of eusocial bee species (*Apis*: Seeley, 1995; *Bombus*: Edwards & Williams, 2004), likely resulting in increased competition. This is because eusocial bee colonies can collect large amounts of nectar and pollen per day to feed their young and to store for later use, for example: *Bombus*, 50 g (Heinrich, 1979) and *Apis mellifera*, >5 kg (Seeley, 1995) per colony. Almost three-quarters of eusocial bee species have peak populations during July and August (73%; not including the primitively eusocial species of *Halicitus* and *Lassioglossum*). Consequently, during these months researchers have observed: (i) considerable overlap in the flower species visited by *Bombus* and *Apis* (e.g. Thomson, 2006; Steffan-Dewenter & Tscharntke, 2000; Balfour et al., 2015b); (ii) intense nectar competition among bee species (e.g. Inouye, 1978; Weatherwax, 1986; Balfour et al., 2013); (iii) foragers competing for flowers containing minute quantities of nectar (c. 0.1 μl; Williams, 1998; Balfour et al., 2015a); (iv) the beginning of marked nectar robbing among honey bee colonies (e.g. Sakofski et al., 1990); (v) the greatest honey bee foraging distances (Couvillon et al., 2014a); and (vi) the highest proportion of honey bee foragers returning with empty crops (Couvillon et al., 2014b). Competition is most likely to be the result of, and to affect, eusocial bee species (Thomson, 2004; Balfour et al., 2015a). However, there is reason

309 to suppose that solitary species may also be impacted by competition from eusocial bees:
310 oligolectic species due to their limited food plants and foraging range (Westrich, 1989;
311 Evertz, 1995) and polylectic species due to their foraging strategies being similar to that of
312 eusocial bees (Roubik 1978; Schaffer et al., 1983). These interactions are likely to have been
313 exacerbated by historical floral declines, as interspecific niche ovelap and competition are
314 known to intensify during periods of resource scarcity (Thomson, 2006).

315 The floral resource supply per individual insect may be more plentiful in spring than
316 summer due to the blooming period of trees (82% species flowering in April-May) and mass-
317 flowering crops (e.g. *Brassica napus*, *Malus*, *Pyrus*, *Vicia*). This is because trees are capable
318 of providing vast quantities of nectar and pollen relative to herbaceous species, as illustrated
319 by recent research which estimated that a single *Tilla cordata* tree attracted the same number
320 of flower-visitors as 6000m^2 of flower-rich chalk grassland at a nearby National Nature
321 Reserve (Balfour et al., 2015b). Indeed, trees are known to be important spring forage sources
322 for honey bee colonies (Coffey & Breen, 1997; Odoux et al., 2014), solitary bees (Chambers,
323 1946) and bumble bee queens (Lye et al., 2009). Likewise, mass-flowering crops, such as
324 oilseed rape, can provide abundant forage for pollinators (e.g. Westphal et al., 2003), but are
325 mostly spring flowering (Scheper et al., 2014).

326 The data also indicate, however, that the majority of extant endangered pollinators are
327 spring-flying (May-June) species (Fig. 3a). Thus implying that the late-summer species most
328 vulnerable to environmental change have already become extinct, and that pollinator
329 conservation efforts, such as agri-environmental schemes, should not focus exclusively on
330 providing late-summer forage (Wood et al., 2017).

331 Pollinators are currently subject to multiple interacting anthropogenic pressures
332 (Vanbergen et al. 2013; Goulson et al., 2015). However, the population decline of vulnerable
333 bee species have consistently been linked to historical reductions of their host plants (e.g.

Carvell et al., 2006; Kleijn & Raemaker, 2008; Scheper et al., 2014). The relationship between pollinating insect phenologies and the timing of the flowering of the plants that they pollinate is a complex one (Dicks et al., 2013). Our results suggest a causal link that may be fundamental to the pattern of pollinator declines and extinctions seen in Britain. As such these topics clearly deserve further research.

Author contributions

NB designed the study, conducted the literature search, analysed the data, and wrote the manuscript. FLWR, JO and MCC contributed to the interpretation of the data and writing of the manuscript.

Funding statement

NB was unfunded.

Conflict of interest

We have no competing interests.

Acknowledgements

We are particularly thankful to Marc Botham, Roger Morris, Mike Edwards, David Streeter, Eva Riley, Julia Balfour, Margaret Couvillon, Kyle Shackleton, the UK Butterfly Monitoring Scheme, the Hoverfly Recording Scheme, and the Bees, Wasps and Ants Recording Society.

References

Abu-Asab, M.S., Peterson, P.M., Shetler, S.G.,Orli, S.S., 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodiv.Cons., 10, 597-612.

Aldridge, G., Inouye, D.W., Forrest, J.R., Barr, W.A., Miller-Rushing, A.J.,2011) Emergence of a mid-season period of low floral resources in a montane meadow ecosystem associated with climate change. J. Ecol. 99, 905-913.

358 Balfour NJ, Garbuzov M, Ratnieks FLW 2013 Longer tongues and swifter handling: why do
359 more bumble bees (*Bombus* spp.) than honey bees (*Apis mellifera*) forage on lavender
360 (*Lavandula* spp.)? Ecol. Entomol. 38, 323-329.
361 Balfour, N.J., Gandy, S., Ratnieks, F.L.W., 2015a. Exploitative competition alters bee
362 foraging and flower choice. Behav. Ecol. Sociobiol. 69, 1731-1738.
363 Balfour NJ, Fensome KA, Samuelson EE, Ratnieks, F.L.W., 2015b. Following the dance:
364 Ground survey of flowers and flower-visiting insects in a summer foraging hotspot identified
365 via honey bee waggle dance decoding. Agric. Ecosyst. Environ. 213, 265-271.
366 Ball, S., Ball, S.G., Morris, R., 2013. Britain's hoverflies: an introduction to the hoverflies of
367 Britain. Princeton University Press, Princeton, U.S.A.
368 Bartomeus, I., Ascher, J.S., Gibbs, J., Danforth, B.N., Wagner, D.L., Hedtke, S.M., Winfree
369 R., 2013. Historical changes in northeastern US bee pollinators related to shared ecological
370 traits. Proc. Natl. Acad. Sci. 110, 4656-4660.
371 Baude, M., et al., 2016. Historical nectar assessment reveals the fall and rise of floral
372 resources in Britain. Nature 530, 85-88.
373 Brickell, C., 2010. *Royal* Horticultural Society encyclopedia of plants and flowers. Dorling
374 Kindersley, London, U.K.
375 Burkle, L.A., Marlin, J.C., Knight, T.M., 2013. Plant-pollinator interactions over 120 years:
376 loss of species, co-occurrence, and function. Science 339, 1611-1615.
377 Brown, J.H., 1984. On the relationship between abundance and distribution of species. Am.
378 Nat. 124, 255-279.
379 Carreck, N.L., Williams, I.H., 2002. Food for insect pollinators on farmland: insect visits to
380 flowers of annual seed mixtures. J. Insect Conserv. 6, 13-23.
381 Carvell, C., Roy, D.B., Smart, S.M., Pywell, R.F., Preston, C.D., Goulson, D, 2006. Declines
382 in forage availability for bumblebees at a national scale. Biol. Con. 132, 481-489.

383 Chambers, V.H., 1946. An examination of the pollen loads of *Andrena*: the species that visit
384 fruit trees. J. Anim. Ecol. 15, 9-21.
385 Cheffings, C.M., Farrel,l L. (Eds), Dines, T.D., Jones, R.A., Leach, S.J., McKean, D.R.,
386 Pearman, D.A., Preston, C.D., Rumsey, F.J., Taylor, I., 2005. *The Vascular Plant Red List for*
387 *Great Britain*. Species Status 7: 1-116. Joint Nature Conservation Committee, Peterborough.
388 Clapham, A.R., Tutin, T.G., Moore, D.M., 1990. *Flora of the British Isles*. Cambridge
389 University Press, Cambridge, UK.
390 Couvillon, M.J., Schürch, R., Ratnieks, F.L.W., 2014a. Waggle dance distances as integrative
391 indicators of seasonal foraging challenges. PloS one, 9, e93495.
392 Couvillon, M.J., Fensome, K.A., Quah, S.K., Schürch, R., 2014b, Summertime blues: August
393 foraging leaves honey bees empty-handed. Commun. Integr. Biol. 7, e28821.
394 Dicks, L.V., Baude, M., Roberts, S.P., Phillips, J., Green, M. and Carvell, C., 2015. How
395 much flower-rich habitat is enough for wild pollinators? Answering a key policy question
396 with incomplete knowledge. Ecological Entomology, 40, 22-35.
397 Dugan, P.J., 1990. *Wetland Conservation. A Review of Current Issues and Required Action.*
398 IUCN, Gland, Switzerland.
399 Edwards, M., Williams, P., 2004. Where have all the bumblebees gone, and could they ever
400 return? *Br. Wildlife*, 15, 305-312.
401 Evans, E. E., Transhumance in Europe. Geography, 25, 172-180.
402 Evertz, S., 1995. Inter-specific competition amongst honey-bees (*Apis mellifera*) and solitary
403 wild bees (Hymenoptera Apoidea). Natur Landschaft 70, 165–172
404 Falk, S., 1991. *A review of the scarce and threatened bees, wasps and ants of Great Britain*
405 (No. 35). Nature Conservancy Council for England, Peterborough, U.K.
406 Falk, S.J., 2015. *Field guide to the bees of Great Britain and Ireland*. British Wildlife
407 Publishing, Totnes, U.K.

408 Fitter, A.H., Peat, H.J., 1994. The Ecological Flora Database. J. Ecol. 82, 415-425.
409 Fitzpatrick, U., Murray, T.E., Paxton, R.J., Breen, J., Cotton, D., Santurum, V., Brown,
410 M.J.F, 2007. Rarity and decline in bumblebees – A test of causes and correlates in the Irish
411 fauna. Biolog. Conserv., 136, 185-194.
412 Fox, R., Warren, M.S., Brereton, T.M., Roy, D.B., Robinson, A., 2011. A new Red List of
413 British butterflies. Insect Conserv. Diver. 4,159-172.
414 Fuller, R.M., 1987. The changing extent and conservation interest of lowland grasslands in
415 England and Wales: a review of grassland surveys 1930–1984. Biolog. Conserv., 40, 281-
416 300.
417 Gaston, K.J., Blackburn, T.M., Lawton, J.H., 1997. Interspecific abundance-range size
418 relationships: an appraisal of mechanisms. J. An. Ecol. 66, 579-601.
419 Goulson, D., 2003. *Bumblebees: their behaviour and ecology*. Oxford University Press,
420 Oxford.
421 Goulson, D., Nicholls, E., Botías, C., Rotheray, E.L. 2015. Bee declines driven by combined
422 stress from parasites, pesticides, and lack of flowers. *Science* 347, 1255957.
423 Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans,
424 W., Müller, A., Sumser, H., Hörren, T.,Goulson, D., de Kroon, H., 2017. More than 75
425 percent decline over 27 years in total flying insect biomass in protected areas. Plos One 12:
426 e0185809.
427 Heinrich, B. 1979., *Bumblebees Economics*. Harvard University Press, London.
428 Hill, M.O., Preston, C.D., Roy, D.B., 2004. *PLANTATT – Attributes of British and Irish*
429 *Plants: Status, Size, Life History, Geography and Habitats.* Centre for Ecology and
430 Hydrology, Huntingdon, UK.

Holland, J.M., Smith, B.S., Storkey, J., Lutman, P.J.W. and Aebischer, N.J. 2015. Managing habitats on English farmland for insect pollinator conservation. Biological Conservation, 182, 215-222.

Horn, J., Becher, M.A., Kennedy, P.J., Osborne, J.L., Grimm, V., 2015. Multiple stressors: using the honeybee model BEEHAVE to explore how spatial and temporal forage stress affects colony resilience. Oikos 125, 1001-1016.

Inouye, D.W., 1978. Resource partitioning in bumble bees: experimental studies of foraging behaviour. Ecology 59, 672-678.

Karem, J., Woods, S.A., Drummond, F., Stubbs, C., 2010. The relationships between *Apocrita* wasp populations and flowering plants in Maine's wild lowbush blueberry agroecosystems. *Biocontrol Sci. Techn.* 20, 257-274

Kearns, C.A., Inouye, D.W., Waser, N.M., 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annu. Rev. Ecol. Evol. Syst. 29, 83-112.

Klein, A.M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. *Proc. R. Soc. Lond. B Biol. Sci.* 274, 303-313.

Kunte, K., 2008. Competition and species diversity: removal of dominant species increases diversity in Costa Rican butterfly communities. Oikos, 117, 69-76.

Lack, A.J., 1982. The ecology of flowers of chalk grassland and their insect pollinators. J. Ecol. 70, 773-790.

Loescher, W.H., McCamant, T., Keller, J.D. 1990. Carbohydrate reserves, translocation, and storage in woody plant roots. *Hort. Sci.* 25, 274-281.

Lye, G., Park, K., Osborne, J., Holland, J., Goulson, D., 2009. Assessing the value of Rural Stewardship schemes for providing foraging resources and nesting habitat for bumblebee queens (Hymenoptera: Apidae). Biol. Con. 142, 2023-2032.

456 Meyer, B., Jauker, F., Steffan-Dewenter, I., 2009. Contrasting resource-dependent responses
457 of hoverfly richness and density to landscape structure. Basic Appl. Ecol. 10, 178-186.
458 Mosquin, T., 1971. Competition for pollinators as a stimulus for the evolution of flowering
459 time. Oikos, 22, 398-402.
460 Moulin, S., Kergoat, L., Viovy, N., Dedieu, G., 1997. Global-scale assessment of vegetation
461 phenology using NOAA/AVHRR satellite measurements. J. Clim. 10, 1154-1170.
462 by
463 Ollerton, J., Winfree, R., Tarrant, S., 2011. How many flowering plants are pollinated by
464 animals? Oikos 120, 321-326.
465 Ollerton, J., Erenler, H., Edwards, M., Crockett, R., 2014. Extinctions of aculeate pollinators
466 in Britain and the role of large-scale agricultural changes. Science 346. 1360-1362.
467 Pope, N.S., Jha, S., 2018. Seasonal food scarcity prompts long-distance foraging by a wild
468 social bee. *Am. Nat.*, 191, 45-57.
469 Potts, S. G., et al., 2010. Global pollinator declines: trends, impacts and drivers. Trends Ecol.
470 Evol. 25, 345–353.
471 R-Project, 2017. R: A Language and Environment for Statistical Computing. R Foundation,
472 Vienna, Austria. URL http://www.r-project.org/. Accessed 10 April 2017
473 Rathcke, B., Lacey, E.P., 1985. Phenological patterns of terrestrial plants. Ann. Rev. Ecol.
474 Systemat. 16, 179-214.
475 Robinson, R.A., Sutherland, W.J., 2002. Post-war changes in arable farming and biodiversity
476 in Great Britain. *J Appl. Ecol.* 39, 157-176.
477 Roy, D.B., Rothery, P., Brereton, T., 2007. Reduced-effort schemes for monitoring butterfly
478 populations. J. Appl. Ecol. 44, 993-1000.
479 Roubik, D.W., 1978. Competitive interactions between neotropical pollinators and
480 africanized honey bees. Science 201, 1030– 1032.

481 Sakofski, F., Koeniger, N., Fuchs, S, 1990. Seasonality of honey bee colony invasion by
482 *Varroa jacobsoni* Oud. Apidologie 21, 547-550.
483 Schaffer, W.M., Zeh, D.W., Buchmann, S.L., Kleinhans, S., Schaffer, M.V., Antrim, J., 1983.
484 Competition for nectar between introduced honey bees and native North American bees and
485 ants. Ecology 64, 564–577.
486 Scheper, J., Reemer, M.., van Kats R., Ozinga, W.A., van der Linden, G.T., Schaminée, J.H.,
487 Kleijn, D, 2014 Museum specimens reveal loss of pollen host plants as key factor driving
488 wild bee decline in The Netherlands. *Proc. Nat. Acad. Scien.* **111**, 17552-17557.
489 Shavit, O., Dafni, A. and Ne'eman, G., 2009. Competition between honeybees (*Apis*
490 mellifera) and native solitary bees in the Mediterranean region of Israel—Implications for
491 conservation. Israel Journal of Plant Sciences, 57, 171-183.
492 Seeley, T.D., 1995. *The wisdom of the hive: the social physiology of honey bee colonies*.
493 Harvard University Press, Cambridge, MA.
494 Spradberry, J.P., 1973. *Wasps: an account of the biology and natural history of solitary and*
495 *social wasps*. Sidgwick and Jackson, London.
496 Steffan-Dewenter, I., Tscharntke, T., 2000. Resource overlap and possible competition
497 between honey bees and wild bees in central Europe. *Oecologia* 122, 288-296.
498 Stroh, P.A., et al., 2014. *A Vascular Plant Red List for England*. Botanical Society of Britain
499 and Ireland, Bristol.
500 Thomson, D.M., 2006. Detecting the effects of introduced species: a case study of
501 competition between *Apis* and *Bombus*. Oikos, 114, 407-418.
502 Tepedino, V.J., Stanton, N.L., 1981. Diversity and competition in bee-plant communities on
503 short-grass prairie. Oikos 36, 35-44.

504 Thompson, D.B.A., MacDonald, A.J., Marsden, J.H., Galbraith, C.A., 1995. Upland heather
505 moorland in Great Britain: a review of international importance, vegetation change and some
506 objectives for nature conservation. Biol. Conserv. 71, 163-178.
507 Thomas, J.A., Simcox, D.J., Hovestadt, T., 2011. Evidence based conservation of butterflies.
508 *J. Insect Conserv*. 15, 241-258.
509 Thomson, D., 2004. Competitive interactions between the invasive European honey bee and
510 native bumble bees. Ecology 85, 458-470.
511 Thomson, D.M., 2006. Detecting the effects of introduced species: a case study of
512 competition between *Apis* and *Bombus*. Oikos, 114, 407-418.
513 Torné-Noguera, A., Rodrigo, A., Osorio, S. and Bosch, J., 2016. Collateral effects of
514 beekeeping: impacts on pollen-nectar resources and wild bee communities. Basic Appl. Ecol.,
515 17, 199-209.
516 UKBMS, 2017. *Butterflies for the New Millennium*, Accessed 20th February 2017,
517 http://butterfly-conservation.org/111/butterflies-for-the-new-millennium.html
518 Vanbergen, A.J., 2013. Threats to an ecosystem service: pressures on pollinators. Front. Ecol.
519 Environ. 11, 251-259.
520 Waldbauer, G.P., LaBerge, W.E., 1985. Phenological relationships of wasps, bumblebees,
521 their mimics and insectivorous birs in northern Michigan. Ecol. Entomol. 10, 99-110.
522 Waldbauer, G.P., 1988. Asynchrony between Batesian mimics and their models. Am. Nat.,
523 131, 103-121.
524 Westphal, C., Steffan-Dewenter, I., Tscharntke, T., 2003. Mass flowering crops enhance
525 pollinator densities at a landscape scale. Ecol. Lett. 6, 961-965.
526 Westrich, P., 1989. *Die Wildbienen Baden Württembergs*. Eugen Ulmer, Stuttgart.
527 Wetherwax P.B., 1986. Why do honeybees reject certain flowers? Oecologia 69, 567-570.

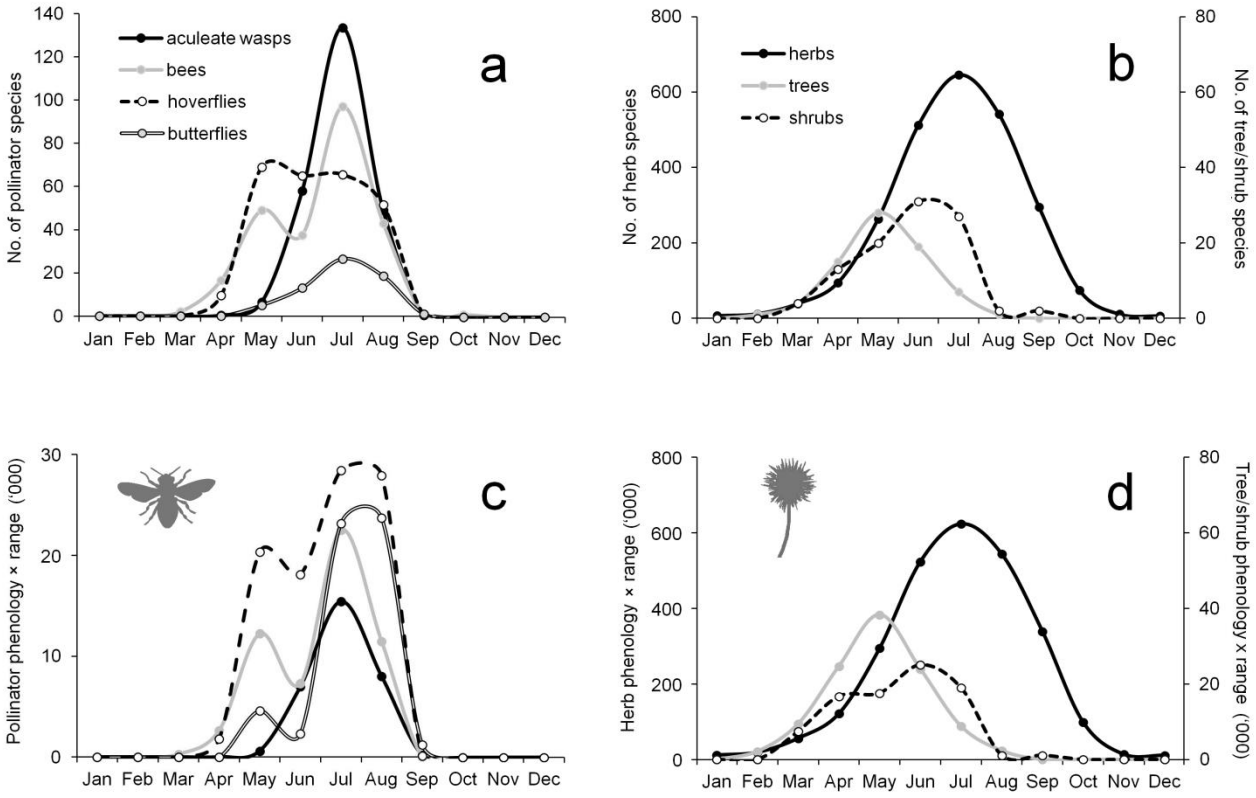
528 Williams, C.S., 1998. The identity of the previous visitor influences flower rejection by
529 nectar-collecting bees. Anim. Beh. 56, 673-681.
530 Williams, P.H., Osborne, J.L., 2009. Bumblebee vulnerability and conservation world-wide.
531 Apidologie 40, 367-387.
532 Willis, C.G., Ruhfel, B., Primack, R.B., Miller-Rushing, A.J., Davis, C.C., 2008.
533 Phylogenetic patterns of species loss in Thoreau's woods are driven by climate change. *P.*
534 *Natl Acad Sci.* 105, 17029-17033.
535 Wood, T.J., Holland, J.M. and Goulson, D., 2017. Providing foraging resources for solitary
536 bees on farmland: current schemes for pollinators benefit a limited suite of species. *J. Appl.*
537 *Ecol.* 54, 323-333.

538 **Fig. 1** a) Peak numbers of observations of British pollinator species, by calendar month,
539 grouped into aculeate wasps, bees, hoverflies and butterflies b) Numbers of species of
540 flowering British insect-pollinated plants per month, grouped into herbs, trees and shrubs.

Fig. 2 Relationship between the number of British flower-visiting insect species recorded on the wing and the number of insect-pollinated herb and tree/shrub species in flower, per calendar month. There are two significant positive relationships shown by the regression lines.

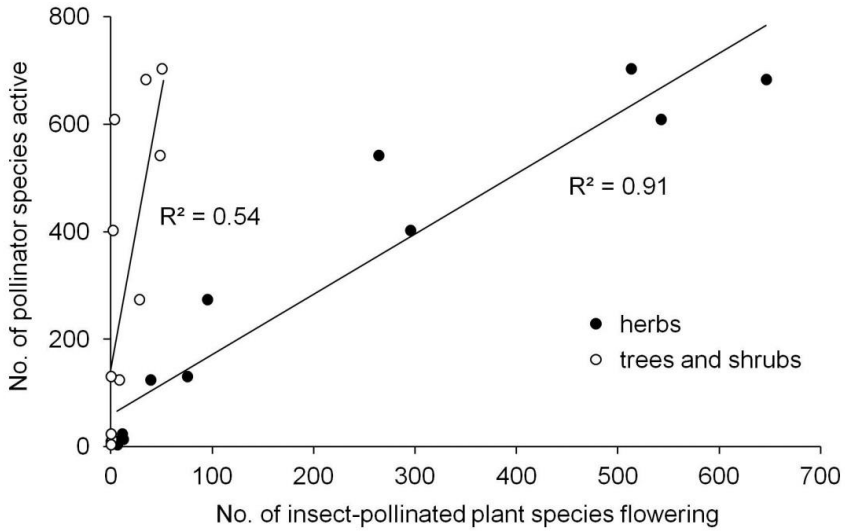
Fig. 3 Observed minus the expected (a) phenology of extinct (n = 40 species) and critically endangered/endangered (n = 33) British pollinator species and (b) flowering phenology of extinct and critically endangered/endangered insect-pollinated British plant species (n = 57).

548 **Figure 1**



549

550 **Figure 2**



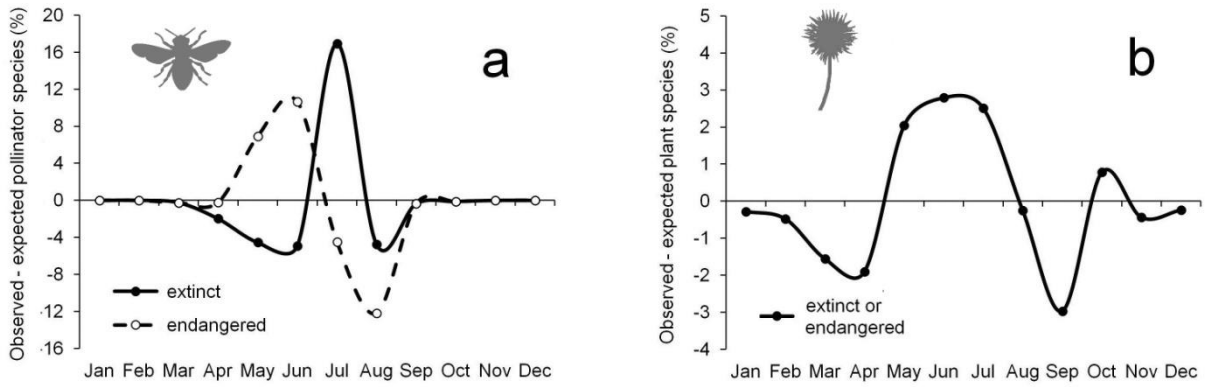
551

552

553

554 **Figure 3**

555



Appendix S1 - Peak number of aculeate wasp observations per species, per calendar month (J = January etc.) calculated from the Bees, Wasps & Ants Recording Society and the Global Biodiversity Information Facility databases. Records from all years were binned per month for all species with ≥50 total observations (90%; 248 out of 276 species). When the difference between the two months with the greatest number of insect observations was <10%, the peak abundance of a species was considered to be spread across both months (e.g. *Agenioideus cinctellus* observations are equal and maximal in June and July, resulting in each month being 'scored' 0.5 for this species). When the difference was >10% the peak abundance of a species was considered to peak in only one month (e.g. *Agenioideus sericeus* peak observations are in August, resulting in this month being 'scored' 1 for this species).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Records	Hectads	Source
Agenioideus cinctellus						0.5	0.5						457	131	BWARS
Agenioideus sericeus								1					55	1	BWARS/GBIF
Ammophila pubescens							1						604	42	BWARS
Ammophila sabulosa							1						2053	268	BWARS
Ancistrocerus antilope													17	15	BWARS
Ancistrocerus gazella							1						1288	335	BWARS
Ancistrocerus nigricornis								1					409	125	BWARS
Ancistrocerus oviventris						1							529	232	BWARS
Ancistrocerus parietinus						1							527	198	BWARS
Ancistrocerus parietum							1						470	210	BWARS
Ancistrocerus scoticus						1							449	175	BWARS
Ancistrocerus trifasciatus							1						934	312	BWARS
Anoplius caviventris							0.5	0.5					104	26	BWARS/GBIF
Anoplius concinnus							1						182	93	BWARS
Anoplius infuscatus							0.5	0.5					665	177	BWARS
Anoplius nigerrimus								1					1497	375	BWARS
Anoplius viaticus								1					997	122	BWARS
Anteon arcuatum						1							61	14	BWARS/GBIF

Anteon brachycerum					1								66	17	BWARS
Anteon ephippiger							1						79	15	GBIF
Anteon exiguum								1					52	2	BWARS/GBIF
Anteon flavicorne													54	13	BWARS/GBIF
Anteon fulviventre						1							86	22	BWARS
Anteon gaullei							1						71	19	BWARS
Anteon infectum						1							98	11	BWARS
Anteon jurineanum					1								110	24	BWARS
Anteon pubicorne						0.5	0.5						191	42	BWARS
Anteon reticulatum													1	1	BWARS
Anteon scapulare						1							63	4	BWARS
Anteon tripartitum													16	7	BWARS
Aphelopus atratus						1							84	21	BWARS
Aphelopus melaleucus						1							139	31	BWARS
Aphelopus nigriceps													7	5	BWARS
Aphelopus querceus													4	3	BWARS
Aphelopus serratus						1							57	19	BWARS/GBIF
Aporus unicolor								1					185	52	BWARS
Arachnospila anceps								1					1831	415	BWARS
Arachnospila consobrina							1						85	11	BWARS/GBIF
Arachnospila minutula								1					292	97	BWARS
Arachnospila rufa							1						365	1	BWARS/GBIF
Arachnospila spissa						1							856	255	BWARS
Arachnospila trivialis								1					414	112	BWARS
Arachnospila wesmaeli								1					93	33	BWARS
Argogorytes fargeii						1							90	35	BWARS
Argogorytes mystaceus						1							1010	309	BWARS
Astata boops							1						1002	136	BWARS
Auplopus carbonarius						1							338	77	BWARS
Bethylus boops													12	7	BWARS
Bethylus cephalotes							1						132	52	BWARS

Bethylus dendrophilus													6	4	BWARS
Bethylus fuscicornis							1						115	52	BWARS
Caliadurgus fasciatellus								1					464	136	BWARS
Cephalonomia formiciformis													17	8	BWARS
Cerceris arenaria							1						1811	238	BWARS
Cerceris quadricincta							0.5	0.5					73	15	BWARS
Cerceris quinquefasciata							1						216	46	BWARS
Cerceris ruficornis							1						402	68	BWARS
Cerceris rybyensis							1						2330	291	BWARS
Cerceris sabulosa							1						82	1	BWARS/GBIF
Ceropales maculata							0.5	0.5					273	87	BWARS
Ceropales variegata								1					72	14	BWARS/GBIF
Chrysis angustula						1							856	276	BWARS
Chrysis fulgida						1							54	22	BWARS
Chrysis gracillima							1						73	42	BWARS
Chrysis ignita						1							189	86	BWARS
Chrysis illigeri						0.5	0.5						245	60	BWARS
Chrysis impressa						1							752	239	BWARS
Chrysis longula							1						112	3	BWARS/GBIF
Chrysis mediata						1							127	73	BWARS
Chrysis pseudobrevitarsis						0.5	0.5						52	3	BWARS/GBIF
Chrysis ruddii						1							131	56	BWARS
Chrysis rutiliventris						0.5	0.5						244	123	BWARS
Chrysis schencki						0.5	0.5						298	24	BWARS/GBIF
Chrysis viridula						1							413	138	BWARS
Chrysura hirsuta					0.5	0.5							129	3	BWARS/GBIF
Chrysura radians						1							99	46	BWARS
Cleptes nitidulus							1						74	37	BWARS
Cleptes semiauratus							1						108	66	BWARS
Crabro cribrarius							1						1201	313	BWARS
Crabro peltarius						0.5	0.5						804	186	BWARS

Crabro scutellatus							1						233	49	BWARS
Crossocerus annulipes							1						1206	309	BWARS
Crossocerus binotatus							1						172	83	BWARS
Crossocerus capitosus						0.5	0.5						266	143	BWARS
Crossocerus cetratus						1							697	238	BWARS
Crossocerus congener								1					39	3	BWARS/GBIF
Crossocerus dimidiatus							1						426	192	BWARS
Crossocerus distinguendus							1						456	114	BWARS
Crossocerus elongatulus							1						1654	438	BWARS
Crossocerus exiguus								1					79	21	BWARS
Crossocerus leucostomus						1							363	20	BWARS/GBIF
Crossocerus megacephalus						1							1499	443	BWARS
Crossocerus nigritus						0.5	0.5						458	184	BWARS
Crossocerus ovalis						0.5	0.5						995	219	BWARS
Crossocerus palmipes							1						78	41	BWARS
Crossocerus podagricus							1						1523	381	BWARS
Crossocerus quadrimaculatus							0.5	0.5					2087	345	BWARS
Crossocerus styrius							1						90	56	BWARS
Crossocerus tarsatus						0.5		0.5					759	232	BWARS
Crossocerus vagabundus							1						305	21	BWARS/GBIF
Crossocerus varus							1						1519	360	BWARS
Crossocerus walkeri							1						69	43	BWARS
Crossocerus wesmaeli							1						1124	184	BWARS
Cryptocheilus notatus							0.5	0.5					186	48	BWARS
Didineis lunicornis								1					130	48	BWARS
Dinetus pictus							1						113	58	BWARS/GBIF
Diodontus insidiosus							1						175	1	BWARS
Diodontus luperus						0.5	0.5						391	50	BWARS
Diodontus minutus							1						890	120	BWARS
Diodontus tristis							1						411	169	BWARS
Dipogon bifasciatus						0.5		0.5					50	98	BWARS

Dipogon subintermedius							1						542	16	BWARS
Dipogon variegatus						0.5	0.5						400	184	BWARS
Dolichovespula media								1					940	147	BWARS
Dolichovespula norwegica							0.5	0.5					472	318	BWARS
Dolichovespula saxonica							0.5	0.5					523	271	BWARS
Dolichovespula sylvestris							0.5	0.5					2300	150	BWARS
Dryinus collaris													1	591	BWARS
Dryinus niger													1	1	BWARS
Dryudella pinguis							1						330	1	BWARS
Ectemnius borealis							0.5	0.5					66	105	BWARS
Ectemnius cavifrons							1						1455	12	BWARS
Ectemnius cephalotes							1						673	369	BWARS
Ectemnius continuus								1					2956	252	BWARS
Ectemnius dives							0.5	0.5					326	531	BWARS
Ectemnius lapidarius							1						555	84	BWARS
Ectemnius lituratus							0.5	0.5					1391	207	BWARS
Ectemnius rubicola							1						394	288	BWARS
Ectemnius ruficornis							1						290	161	BWARS
Ectemnius sexcinctus							1						262	111	BWARS
Elampus panzeri							1						360	108	BWARS
Embolemus ruddii							0.5	0.5					57	78	BWARS/GBIF
Entomognathus brevis							1						921	8	BWARS
Episyron rufipes							1						1181	198	BWARS
Epyris bilineatus													7	215	BWARS
Epyris brevipennis													0	4	BWARS
Epyris niger								1					55	18	BWARS/GBIF
Eumenes coarctatus							0.5	0.5					426	18	BWARS
Euodynerus quadrifasciatus						1							346	42	BWARS/GBIF
Evagetes crassicornis								1					1052	6	BWARS
Evagetes dubius								1					276	267	BWARS
Evagetes pectinipes							1						365	40	BWARS/GBIF

Gonatopus albosignatus													11	6	BWARS
Gonatopus bicolor													15	7	BWARS
Gonatopus clavipes													28	5	BWARS
Gonatopus distinguendus													12	14	BWARS
Gonatopus formicicolus													0	2	BWARS
Gonatopus helleni													5	1	BWARS
Gonatopus lunatus													1	4	BWARS
Gonatopus pedestris													5	2	BWARS
Gonatopus striatus													4	4	BWARS
Goniozus claripennis							1						108	4	BWARS
Gorytes bicintus													0	0	BWARS
Gorytes laticinctus							1						108	37	BWARS
Gorytes quadrifasciatus							1						435	160	BWARS
Gymnomerus laevipes						1							284	89	BWARS
Haplogonatopus oratorius													3	3	BWARS
Harpactus tumidus							1						454	197	BWARS
Hedychridium ardens						1							822	197	BWARS
Hedychridium coriaceum							1						86	21	BWARS
Hedychridium cupreum						0.5	0.5						90	34	BWARS
Hedychridium roseum							1						680	96	BWARS
Hedychrum niemelai							1						428	72	BWARS
Hedychrum rutilans							1						163	1	BWARS/GBIF
Homonotus sanguinolentus							1						1193	11	BWARS
Lestica clypeata						0.5	0.5						286	1	BWARS/GBIF
Lestiphorus bicinctus								1					257	88	BWARS
Lindenius albilabris							1						1842	345	BWARS
Lindenius panzeri							1						516	119	BWARS
Lindenius pygmaeus							1						50	1	BWARS/GBIF
Lonchodryinus ruficornis							1						152	40	BWARS
Mellinus arvensis								1					2438	465	BWARS
Mellinus crabroneus							1						91	12	BWARS/GBIF

Methocha articulata							1						296	68	BWARS
Microdynerus exilis							1						159	73	BWARS
Mimesa bicolor							1						155	22	BWARS/GBIF
Mimesa bruxellensis							1						144	41	BWARS
Mimesa equestris								1					1269	189	BWARS
Mimesa lutaria							1						558	109	BWARS
Mimumesa atratina							1						109	3	BWARS/GBIF
Mimumesa dahlbomi						0.5	0.5						720	247	BWARS
Mimumesa littoralis							0.5	0.5					75	22	BWARS
Mimumesa spooneri							0.5	0.5					79	25	BWARS
Mimumesa unicolor							1						118	29	BWARS
Miscophus ater							1						195	3	BWARS/GBIF
Miscophus concolor							1						199	33	BWARS
Monosapyga clavicornis						1							179	79	BWARS
Mutilla europaea								1					481	69	BWARS
Nitela borealis						0.5		0.5					69	5	BWARS
Nitela lucens						1							96	18	BWARS
Nysson dimidiatus							1						255	112	BWARS
Nysson interruptus						1							60	7	BWARS/GBIF
Nysson spinosus						1							572	211	BWARS
Nysson trimaculatus							1						437	147	BWARS
Odynerus melanocephalus						1							219	80	BWARS
Odynerus reniformis						1							95	2	BWARS/GBIF
Odynerus simillimus							1						75	7	BWARS
Odynerus spinipes						1							615	216	BWARS
Omalus aeneus							1						148	60	BWARS
Omalus puncticollis							1						69	45	BWARS
Oxybelus argentatus							1						176	44	BWARS
Oxybelus mandibularis							1						164	40	BWARS
Oxybelus uniglumis							1						2416	360	BWARS
Passaloecus clypealis							1						71	18	BWARS

Passaloecus corniger							1						698	221	BWARS
Passaloecus eremita						0.5	0.5						339	74	BWARS
Passaloecus gracilis							1						721	197	BWARS
Passaloecus insignis							1						329	148	BWARS
Passaloecus monilicornis							1						96	41	BWARS
Passaloecus singularis						0.5	0.5						959	262	BWARS
Passaloecus turionum							1						57	20	BWARS
Pemphredon inornata						0.5	0.5						1178	323	BWARS
Pemphredon lethifer						0.5	0.5						946	302	BWARS
Pemphredon lugubris						1							1729	418	BWARS
Pemphredon morio							1						162	81	BWARS
Pemphredon mortifer													0	0	BWARS
Pemphredon rugifera						0.5	0.5						146	0	GBIF
Pemphredon wesmaeli							1						246	0	GBIF
Philanthus triangulum								1					1549	251	BWARS
Philoctetes truncatus													2	2	BWARS
Podalonia affinis							1						179	36	BWARS
Podalonia hirsuta							0.5	0.5					355	58	BWARS
Pompilus cinereus							1						901	198	BWARS
Priocnemis agilis								1					103	64	BWARS
Priocnemis confusor								1					142	56	BWARS
Priocnemis cordivalvata								1					102	43	BWARS
Priocnemis coriacea					1								131	67	BWARS
Priocnemis exaltata								1					929	266	BWARS
Priocnemis fennica								1					466	129	BWARS
Priocnemis hyalinata							1						122	52	BWARS
Priocnemis parvula								1					712	236	BWARS
Priocnemis propinqua					1								951	302	BWARS
Priocnemis pusilla								1					407	139	BWARS
Priocnemis schioedtei							1						301	94	BWARS
Priocnemis susterai					1								228	107	BWARS

Psen ater													0	0	BWARS
Psenulus concolor						1							259	120	BWARS
Psenulus pallipes							1						788	274	BWARS
Psenulus schencki							1						110	38	BWARS
Pseudepipona herrichii							1						145	5	BWARS
Pseudisobrachium subcyaneum													2	2	BWARS
Pseudomalus auratus							1						652	229	BWARS
Pseudomalus violaceus							1						130	65	BWARS
Pseudospinolia neglecta						1							115	44	BWARS
Rhopalum clavipes							0.5	0.5					605	257	BWARS
Rhopalum coarctatum						0.5		0.5					777	243	BWARS
Rhopalum gracile								1					76	3	BWARS/GBIF
Sapyga quinquepunctata					0.5	0.5							506	154	BWARS
Smicromyrme rufipes							1						379	53	BWARS
Spilomena beata							1						70	48	BWARS
Spilomena curruca							1						71	46	BWARS
Spilomena enslini				0.5	0.5								56	32	BWARS
Spilomena troglodytes							1						232	103	BWARS
Stigmus pendulus							1						235	65	BWARS
Stigmus solskyi							1						573	189	BWARS
Symmorphus bifasciatus							1						684	264	BWARS
Symmorphus connexus							1						217	15	BWARS/GBIF
Symmorphus crassicornis						1							148	32	BWARS
Symmorphus gracilis						0.5	0.5						530	174	BWARS
Tachysphex nitidus						1							145	53	BWARS
Tachysphex obscuripennis							1						2706	1	BWARS/GBIF
Tachysphex pompiliformis						0.5	0.5						1350	302	BWARS
Tachysphex unicolor						1							127	18	BWARS/GBIF
Tiphia femorata								1					778	166	BWARS
Tiphia minuta						1							361	170	BWARS
Trichrysis cyanea						0.5	0.5						1562	371	BWARS

Trypoxylon attenuatum							0.5	0.5					1293	354	BWARS
Trypoxylon clavicerum							1						1167	318	BWARS
Trypoxylon figulus							1						184	216	BWARS
Trypoxylon medium							1						565	158	BWARS
Trypoxylon minus						0.5	0.5						1471	1	BWARS/GBIF
Vespa crabro								0.5	0.5				1766	388	BWARS
Vespula austriaca						1							99	53	BWARS
Vespula germanica								1					2213	461	BWARS
Vespula rufa								1					1560	443	BWARS
Vespula vulgaris								1					4767	673	BWARS
Totals	**0**	**0**	**0**	**0.5**	**6.5**	**58**	**133.5**	**49**	**0.5**	**0**	**0**	**0**	**133869**	**32177**	

556

557

Appendix S2 - Peak number of observations per bee species, per calendar month (J = January) calculated from the Bees, Wasps & Ants Recording Society and the Global Biodiversity Information Facility databases. Records from all years were binned per month for all species with ≥50 total observations (97%; 247 out of 254 species). When the difference between the two months with the greatest number of insect observations was <10%, the peak abundance of a species was considered to be spread across both months (e.g. *Andrena alfkenella* observations are equal and maximal in June and August, resulting in each month being 'scored' 0.5 for this species). When the difference was >10% the peak abundance of a species was considered to peak in only one month (e.g. *Andrena angustior* peak observations are in May, resulting in this month being 'scored' 1 for this species).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Records	Hectads	Source
Andrena alfkenella							0.5	0.5					154	67	BWARS
Andrena angustior					1								649	186	BWARS
Andrena apicata			1										317	83	BWARS
Andrena argentata							0.5	0.5					621	38	BWARS
Andrena barbilabris					1								1838	308	BWARS
Andrena bicolor							1						4540	638	BWARS
Andrena bimaculata							1						607	102	BWARS
Andrena bucephala					1								405	107	BWARS
Andrena carantonica					1								4979	729	BWARS
Andrena chrysosceles					1								2954	473	BWARS
Andrena cineraria					1								1903	390	BWARS
Andrena clarkella			0.5	0.5									1900	400	BWARS
Andrena coitana							1						516	184	BWARS
Andrena congruens				1									153	27	BWARS
Andrena denticulata							1						1055	258	BWARS
Andrena dorsata							1						3619	368	BWARS
Andrena falsifica					1								118	44	BWARS
Andrena ferox					1								84	11	BWARS
Andrena flavipes				0.5			0.5						6393	423	BWARS
Andrena florea						1							550	42	BWARS
Andrena fucata						1							1072	330	BWARS

Andrena fulva				1									3071	533	BWARS
Andrena fulvago						1							215	100	BWARS
Andrena fuscipes								1					1424	187	BWARS
Andrena gravida				1									52	16	BWARS
Andrena haemorrhoa					1								6054	829	BWARS
Andrena hattorfiana							1						439	81	BWARS
Andrena helvola					1								940	226	BWARS
Andrena humilis					0.5	0.5							556	174	BWARS
Andrena labialis						1							820	189	BWARS
Andrena labiata					1								838	194	BWARS
Andrena lapponica					1								648	159	BWARS
Andrena lathyri					1								950	2	BWARS/GBIF
Andrena lepida													3	1	BWARS
Andrena marginata								1					472	98	BWARS
Andrena minutula							1						4315	522	BWARS
Andrena minutuloides							1						456	83	BWARS
Andrena nana					0.5		0.5						52	3	BWARS/GBIF
Andrena nigriceps							1						185	79	BWARS
Andrena nigroaenea					1								3811	601	BWARS
Andrena nigrospina						1							108	20	BWARS
Andrena nitida				0.5	0.5								3278	494	BWARS
Andrena nitidiuscula							1						311	50	BWARS
Andrena niveata						1							67	21	BWARS
Andrena ovatula							1						1463	238	BWARS
Andrena pilipes								1					286	65	BWARS
Andrena polita													10	2	BWARS
Andrena praecox				1									817	189	BWARS
Andrena proxima					1								282	91	BWARS
Andrena ruficrus				1									130	29	BWARS
Andrena semilaevis						1							1997	441	BWARS

Andrena similis					1								256	109	BWARS
Andrena simillima							1						84	18	BWARS
Andrena subopaca					1								2700	477	BWARS
Andrena synadelpha					1								2643	160	BWARS
Andrena tarsata							1						590	173	BWARS
Andrena thoracica							1						530	163	BWARS
Andrena tibialis				1									1036	98	BWARS
Andrena tridentata													6	4	BWARS
Andrena trimmerana				1									986	184	BWARS
Andrena vaga				1									2275	3	BWARS/GBIF
Andrena varians				1									298	101	BWARS
Andrena wilkella						1							1855	443	BWARS
Anthidium manicatum							1						1019	284	BWARS
Anthophora bimaculata							1						1460	150	BWARS
Anthophora furcata							1						944	291	BWARS
Anthophora plumipes				1									1985	387	BWARS
Anthophora quadrimaculata							1						435	78	BWARS
Anthophora retusa					1								126	57	BWARS
Apis mellifera							1						3080	432	BWARS
Bombus barbutellus							1						738	359	BWARS
Bombus bohemicus							0.5	0.5					2145	643	BWARS
Bombus campestris								1					1500	575	BWARS
Bombus cryptarum					1								75	52	BWARS
Bombus cullumanus								1					53	12	BWARS/GBIF
Bombus distinguendus								1					1115	212	BWARS
Bombus hortorum							1						7806	1466	BWARS
Bombus humilis								1					1355	300	BWARS
Bombus hypnorum						1							3420	721	BWARS
Bombus jonellus							0.5	0.5					2599	719	BWARS
Bombus lapidarius							0.5	0.5					12471	1188	BWARS

Bombus lucorum							1						11824	1575	BWARS
Bombus magnus							1						832	332	BWARS
Bombus monticola						1							1583	341	BWARS
Bombus muscorum							0.5	0.5					2097	523	BWARS
Bombus pascuorum							0.5	0.5					19293	1732	BWARS
Bombus pomorum								1					94	1	BWARS/GBIF
Bombus pratorum						1							8761	1253	BWARS
Bombus ruderarius							1						1081	342	BWARS
Bombus ruderatus							1						393	177	BWARS
Bombus rupestris								1					1032	332	BWARS
Bombus soroeensis							1						712	282	BWARS
Bombus subterraneus								1					226	114	BWARS
Bombus sylvarum								1					886	276	BWARS
Bombus sylvestris						1							2055	633	BWARS
Bombus terrestris							1						11330	1093	BWARS
Bombus vestalis							1						4544	711	BWARS
Ceratina cyanea					0.5	0.5							547	57	BWARS
Chelostoma campanularum							1						656	187	BWARS
Chelostoma florisomne						1							559	240	BWARS
Coelioxys afra							1						54	1	BWARS/GBIF
Coelioxys conoidea							1						359	95	BWARS
Coelioxys elongata							1						416	134	BWARS
Coelioxys inermis							1						194	102	BWARS
Coelioxys mandibularis							1						95	17	BWARS
Coelioxys quadridentata						0.5	0.5						69	34	BWARS
Coelioxys rufescens							1						319	121	BWARS
Colletes cunicularius				1									140	23	BWARS
Colletes daviesanus							1						1588	373	BWARS
Colletes floralis							1						279	34	BWARS
Colletes fodiens							1						900	181	BWARS

Colletes halophilus									1				333	54	BWARS
Colletes hederae										1			754	132	BWARS
Colletes marginatus							1						240	45	BWARS
Colletes similis							1						1067	211	BWARS
Colletes succinctus								1					1921	350	BWARS
Dasypoda hirtipes							1						675	115	BWARS
Dufourea halictula							1						284	1	BWARS/GBIF
Dufourea minuta							1						61	3	BWARS/GBIF
Epeolus cruciger								1					1240	170	BWARS
Epeolus variegatus							1						1225	248	BWARS
Eucera longicornis						1							398	138	BWARS
Eucera nigrescens					1								157	15	BWARS/GBIF
Halictus confusus							0.5	0.5					151	29	BWARS
Halictus eurygnathus								1					51	11	BWARS
Halictus maculatus							1						315	6	BWARS/GBIF
Halictus rubicundus					0.5			0.5					3033	707	BWARS
Halictus subauratus						0.5	0.5						123	0	GBIF
Halictus tumulorum								1					4190	602	BWARS
Heriades rubicola													0	0	BWARS
Heriades truncorum							1						246	40	BWARS
Hoplitis claviventris						0.5	0.5						593	184	BWARS
Hoplitis leucomelana							1						281	0	GBIF
Hylaeus brevicornis							1						1193	320	BWARS
Hylaeus communis							1						3089	475	BWARS
Hylaeus confusus							1						983	248	BWARS
Hylaeus cornutus							1						459	102	BWARS
Hylaeus dilatatus							1						1260	196	BWARS
Hylaeus hyalinatus						0.5	0.5						1326	329	BWARS
Hylaeus incongruus							1						167	35	BWARS
Hylaeus pectoralis							1						163	49	BWARS

Hylaeus pictipes							1						229	55	BWARS
Hylaeus punctulatissimus						1							102	0	GBIF
Hylaeus signatus							1						554	130	BWARS
Lasioglossum albipes								1					2549	538	BWARS
Lasioglossum angusticeps								1					94	17	BWARS
Lasioglossum brevicorne						1							190	41	BWARS
Lasioglossum calceatum							0.5	0.5					5762	802	BWARS
Lasioglossum cupromicans						0.5	0.5						587	173	BWARS
Lasioglossum fratellum								1					1556	354	BWARS
Lasioglossum fulvicorne							0.5	0.5					2221	360	BWARS
Lasioglossum laeve													0	0	BWARS
Lasioglossum laevigatum					0.5	0.5							780	182	BWARS
Lasioglossum laticeps							1						70	8	BWARS
Lasioglossum lativentre					0.5	0.5							981	264	BWARS
Lasioglossum leucopus							0.5	0.5					1999	494	BWARS
Lasioglossum leucozonium								1					3464	493	BWARS
Lasioglossum malachurum							0.5	0.5					2962	269	BWARS
Lasioglossum minutissimum							0.5	0.5					1243	216	BWARS
Lasioglossum morio							0.5	0.5					4787	546	BWARS
Lasioglossum nitidiusculum					0.5			0.5					317	153	BWARS
Lasioglossum parvulum					1								1603	238	BWARS
Lasioglossum pauperatum								1					116	46	BWARS
Lasioglossum pauxillum							1						1634	219	BWARS
Lasioglossum prasinum							1						575	44	BWARS
Lasioglossum punctatissimum						0.5	0.5						1330	265	BWARS
Lasioglossum puncticolle						0.5	0.5						422	80	BWARS
Lasioglossum quadrinotatum								1					142	62	BWARS
Lasioglossum rufitarse						1							857	179	BWARS
Lasioglossum semilucens						1							73	24	BWARS
Lasioglossum sexnotatum						1							418	12	BWARS/GBIF

Lasioglossum smeathmanellum							1						2129	419	BWARS
Lasioglossum villosulum								1					3418	545	BWARS
Lasioglossum xanthopus					1								387	133	BWARS
Lasioglossum zonulum								1					1255	194	BWARS
Macropis europaea							1						418	74	BWARS
Megachile centuncularis							1						1143	366	BWARS
Megachile circumcincta						1							276	111	BWARS
Megachile lapponica								1					249	1	BWARS/GBIF
Megachile leacella							1						567	107	BWARS
Megachile ligniseca							1						826	247	BWARS
Megachile maritima							1						684	170	BWARS
Megachile versicolor							1						1253	303	BWARS
Megachile willughbiella							1						1877	465	BWARS
Melecta albifrons				1									382	167	BWARS
Melecta luctuosa					1								84	9	BWARS/GBIF
Melitta dimidiata							1						748	8	BWARS
Melitta haemorrhoidalis							1						659	113	BWARS
Melitta leporina							1						2438	166	BWARS
Melitta tricincta							1						683	119	BWARS
Nomada argentata								1					88	32	BWARS
Nomada armata							1						66	21	BWARS
Nomada baccata								1					316	31	BWARS
Nomada conjungens					1								54	14	BWARS/GBIF
Nomada errans													10	1	BWARS
Nomada fabriciana					1								2356	501	BWARS
Nomada ferruginata				1									69	53	BWARS
Nomada flava					1								2740	479	BWARS
Nomada flavoguttata					1								2229	473	BWARS
Nomada flavopicta							1						428	141	BWARS
Nomada fucata							1						1720	267	BWARS

Nomada fulvicornis				1									510	123	BWARS
Nomada goodeniana					1								2766	571	BWARS
Nomada guttulata					1								115	19	BWARS/GBIF
Nomada hirtipes					1								140	49	BWARS
Nomada integra						1							223	87	BWARS
Nomada lathburiana					1								731	193	BWARS
Nomada marshamella					1								3043	241	BWARS
Nomada obtusifrons							1						109	60	BWARS
Nomada panzeri					1								1339	426	BWARS
Nomada roberjeotiana							1						99	43	BWARS
Nomada ruficornis					1								1622	461	BWARS
Nomada rufipes								1					1813	306	BWARS
Nomada sexfasciata					1								96	10	BWARS/GBIF
Nomada sheppardana					1								290	103	BWARS
Nomada signata				1									169	62	BWARS
Nomada striata						1							559	229	BWARS
Osmia aurulenta						1							665	142	BWARS
Osmia bicolor					1								959	158	BWARS
Osmia bicornis					1								2677	741	BWARS
Osmia caerulescens						1							1446	315	BWARS
Osmia inermis						1							85	4	BWARS/GBIF
Osmia leaiana						1							1038	300	BWARS
Osmia niveata						1							86	1	GBIF
Osmia parietina					0.5	0.5							88	28	BWARS
Osmia pilicornis					1								202	52	BWARS
Osmia spinulosa							1						1439	231	BWARS
Osmia uncinata						1							342	16	BWARS/GBIF
Osmia xanthomelana					0.5	0.5							226	10	BWARS/GBIF
Panurgus banksianus							1						634	166	BWARS
Panurgus calcaratus							1						915	114	BWARS

Rophites quinquespinosus							1						52	0	GBIF
Sphecodes crassus							1						722	245	BWARS
Sphecodes ephippius					1								2359	449	BWARS
Sphecodes ferruginatus							0.5	0.5					143	87	BWARS
Sphecodes geoffrellus					0.5		0.5						2029	453	BWARS
Sphecodes gibbus					0.5			0.5					1095	333	BWARS
Sphecodes hyalinatus								1					714	191	BWARS
Sphecodes longulus								1					208	65	BWARS
Sphecodes miniatus						1							80	38	BWARS
Sphecodes monilicornis								1					2106	446	BWARS
Sphecodes niger								1					379	131	BWARS
Sphecodes pellucidus					1								1544	228	BWARS
Sphecodes puncticeps								1					1017	272	BWARS
Sphecodes reticulatus								1					437	130	BWARS
Sphecodes rubicundus						1							264	94	BWARS
Sphecodes scabricollis								1					122	40	BWARS
Sphecodes spinulosus					1								108	43	BWARS
Stelis breviuscula							1						97	22	BWARS
Stelis ornatula						0.5	0.5						102	55	BWARS
Stelis phaeoptera							1						71	44	BWARS
Stelis punctulatissima							1						184	85	BWARS
Xylocopa violacea			0.5			0.5							1849	23	BWARS/GBIF
Totals	**0**	**0**	**2**	**16.5**	**49**	**37.5**	**97**	**43**	**1**	**1**	**0**	**0**	**330235**	**57644**	

558

559

Appendix S3 - Peak number of hoverfly observations per species, per calendar month (J = January etc.) calculated from the Hoverfly Recording Society and the Global Biodiversity Information Facility databases. Records from all years were binned per month for all species with ≥50 total observations (92%; 261 out of 284 species). When the difference between the two months with the greatest number of insect observations was <10%, the peak abundance of a species was considered to be spread across both months (e.g. *Brachypalpus laphriformis* observations are equal and maximal in May and June, resulting in each month being 'scored' 0.5 for this species). When the difference was >10% the peak abundance of a species was considered to peak in only one month (e.g. *Anasimyia contracta* peak observations are in June, resulting in this month being 'scored' 1 for this species).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Records	Hectads	Source
Anasimyia contracta						1							977	277	HRS
Anasimyia interpuncta					1								112	25	HRS
Anasimyia lineata						1							1689	422	HRS
Anasimyia lunulata							1						231	51	HRS
Anasimyia transfuga						0.5	0.5						495	172	HRS
Arctophila superbiens								1					782	293	HRS
Baccha elongata							0.5	0.5					1692	567	HRS
Blera fallax						1							380	11	HRS/GBIF
Brachyopa bicolor					1								65	26	HRS
Brachyopa insensilis					1								236	106	HRS
Brachyopa pilosa					1								123	41	HRS
Brachyopa scutellaris					1								660	259	HRS
Brachypalpoides lentus						1							998	327	HRS
Brachypalpus laphriformis					0.5	0.5							348	107	HRS
Caliprobola speciosa						1							92	9	HRS
Callicera aurata							1						151	82	HRS
Callicera rufa						1							72	27	HRS
Callicera spinolae							1						50	14	HRS/GBIF
Chalcosyrphus eunotus					1								102	25	HRS/GBIF
Chalcosyrphus nemorum						1							1600	394	HRS
Chamaesyrphus caledonicus													7	4	HRS
Chamaesyrphus scaevoides						1							135	28	HRS

Cheilosia ahenea					1								56	1	HRS/GBIF
Cheilosia albipila				1									558	260	HRS
Cheilosia albitarsis					1								5760	155	HRS
Cheilosia antiqua					1								609	290	HRS
Cheilosia barbata					1								679	262	HRS
Cheilosia bergenstammi					0.5			0.5					2273	674	HRS
Cheilosia carbonaria								1					138	66	HRS
Cheilosia chrysocoma					1								193	48	HRS
Cheilosia cynocephala								1					149	80	HRS
Cheilosia fraterna					1								1396	557	HRS
Cheilosia griseiventris					1								151	89	HRS
Cheilosia grossa				1									580	269	HRS
Cheilosia illustrata							1						5111	1121	HRS
Cheilosia impressa								1					1539	436	HRS
Cheilosia lasiopa					1								114	76	HRS
Cheilosia latifrons							1						464	221	HRS
Cheilosia longula							1						433	183	HRS
Cheilosia mutabilis						0.5	0.5						260	84	HRS
Cheilosia nebulosa				1									126	57	HRS
Cheilosia nigripes					1								57	27	HRS
Cheilosia pagana					1								6235	1038	HRS
Cheilosia proxima							0.5	0.5					1921	667	HRS
Cheilosia psilophthalma					1								98	8	HRS/GBIF
Cheilosia pubera					1								139	51	HRS
Cheilosia ranunculi					1								110	76	HRS
Cheilosia sahlbergi							1						51	14	HRS/GBIF
Cheilosia scutellata								1					975	319	HRS
Cheilosia semifasciata					1								152	22	HRS
Cheilosia soror								1					438	149	HRS
Cheilosia urbana				0.5	0.5								299	143	HRS
Cheilosia uviformis					1								54	3	HRS/GBIF

Cheilosia variabilis					1								2878	755	HRS
Cheilosia velutina							0.5	0.5					114	72	HRS
Cheilosia vernalis								1					2529	670	HRS
Cheilosia vicina						1							422	168	HRS
Cheilosia vulpina								1					537	217	HRS
Chrysogaster cemiteriorum							1						881	341	HRS
Chrysogaster solstitialis							1						3442	844	HRS
Chrysogaster virescens						1							474	185	HRS
Chrysotoxum arcuatum						1							1190	356	HRS
Chrysotoxum bicinctum							1						4020	876	HRS
Chrysotoxum cautum						1							983	322	HRS
Chrysotoxum elegans						1							272	93	HRS
Chrysotoxum festivum							1						1275	347	HRS
Chrysotoxum octomaculatum nomen						1							56	16	HRS
Chrysotoxum vernale					1								64	15	HRS
Chrysotoxum verralli							1						614	171	HRS
Criorhina asilica					1								474	168	HRS
Criorhina berberina					0.5	0.5							2024	512	HRS
Criorhina floccosa					1								1042	371	HRS
Criorhina ranunculi				1									664	224	HRS
Dasysyrphus albostriatus					1								2929	759	HRS
Dasysyrphus friuliensis					1								80	32	HRS
Dasysyrphus hilaris					1								210	27	HRS/GBIF
Dasysyrphus pinastri						1							78	54	HRS
Dasysyrphus tricinctus					1								1673	551	HRS
Dasysyrphus venustus					1								3620	786	HRS
Didea alneti								1					237	20	HRS/GBIF
Didea fasciata								0.5	0.5				819	273	HRS
Didea intermedia							1						142	65	HRS
Doros profuges						1							96	35	HRS
Epistrophe diaphana						1							307	129	HRS

Epistrophe eligans					1								5166	882	HRS
Epistrophe euchroma					1								83	44	HRS
Epistrophe grossulariae							1						3744	769	HRS
Epistrophe melanostoma					1								70	18	HRS/GBIF
Epistrophe nitidicollis					1								632	224	HRS
Epistrophe ochrostoma													2	1	HRS
Episyrphus balteatus							0.5	0.5					21980	1873	HRS
Eriozona erratica						1							316	13	HRS/GBIF
Eriozona syrphoides								1					269	64	HRS
Eristalinus aeneus							0.5	0.5					837	241	HRS
Eristalinus sepulchralis							0.5	0.5					3467	749	HRS
Eristalis abusivus							1						1053	353	HRS
Eristalis arbustorum								1					11823	1532	HRS
Eristalis cryptarum					0.5			0.5					85	18	HRS
Eristalis horticola							1						4852	1099	HRS
Eristalis intricarius							1						5776	1235	HRS
Eristalis nemorum							0.5	0.5					6830	1172	HRS
Eristalis pertinax								1					19653	1795	HRS
Eristalis rupium							1						488	180	HRS
Eristalis similis							1						144	3	HRS
Eristalis tenax								1					15476	1575	HRS
Eumerus funeralis						0.5		0.5					1734	385	HRS
Eumerus ornatus						1							379	135	HRS
Eumerus sabulonum							1						200	45	HRS
Eumerus strigatus								1					1219	410	HRS
Eupeodes bucculatus					0.5		0.5						139	19	HRS/GBIF
Eupeodes corollae							0.5	0.5					6512	1246	HRS
Eupeodes lapponicus						1							183	1	HRS/GBIF
Eupeodes latifasciatus								1					390	178	HRS
Eupeodes lundbecki								1					452	1	HRS/GBIF
Eupeodes luniger								1					6225	1059	HRS

Eupeodes nielseni						1							89	34	HRS
Eupeodes nitens							1						330	19	HRS/GBIF
Ferdinandea cuprea					0.5	0.5							2674	653	HRS
Ferdinandea ruficornis								1					122	40	HRS/GBIF
Hammerschmidtia ferruginea					0.5	0.5							259	9	HRS/GBIF
Helophilus affinis								1					308	1	HRS/GBIF
Helophilus groenlandicus													4	4	HRS
Helophilus hybridus								1					2075	610	HRS
Helophilus pendulus							0.5	0.5					17366	1707	HRS
Helophilus trivittatus								1					1406	483	HRS
Heringia brevidens													3	3	HRS
Heringia heringi					1								305	150	HRS
Heringia latitarsis													7	7	HRS
Heringia pubescens													6	6	HRS
Heringia senilis													3	3	HRS
Heringia verrucula													3	3	HRS
Heringia vitripennis								1					67	43	HRS/GBIF
Lejogaster metallina						1							2560	846	HRS
Lejogaster tarsata						0.5	0.5						302	114	HRS
Lejops vittatus							1						104	30	HRS
Leucozona glaucia								1					3471	721	HRS
Leucozona laternaria							1						1667	537	HRS
Leucozona lucorum					1								6279	1215	HRS
Mallota cimbiciformis							1						133	64	HRS
Megasyrphus erratica							1						223	81	HRS
Melangyna arctica					0.5		0.5						363	166	HRS
Melangyna barbifrons				1									89	30	HRS/GBIF
Melangyna cincta					1								992	346	HRS
Melangyna compositarum							1						376	198	HRS
Melangyna ericarum													12	5	HRS
Melangyna guttata							1						155	78	HRS

Melangyna labiatarum						1							674	256	HRS
Melangyna lasiophthalma				1									1283	469	HRS
Melangyna quadrimaculata				1									234	127	HRS
Melangyna triangulifera					1								240	112	HRS
Melangyna umbellatarum								1					741	362	HRS
Melanogaster aerosa								1					273	100	HRS
Melanogaster hirtella						1							3816	1060	HRS
Melanostoma dubium						1							73	53	HRS
Melanostoma mellinum							0.5	0.5					10972	1654	HRS
Melanostoma scalare					1								15542	1746	HRS
Meligramma euchromum													31	18	HRS
Meligramma guttatum							0.5	0.5					58	12	HRS/GBIF
Meligramma trianguliferum					1								162	19	HRS/GBIF
Meliscaeva auricollis						0.5	0.5						2855	729	HRS
Meliscaeva cinctella								1					3960	858	HRS
Merodon equestris						1							3551	708	HRS
Metasyrphus lapponicus													15	11	HRS
Metasyrphus latifasciatus								1					1846	576	HRS
Metasyrphus latilunulatus							1						182	91	HRS
Metasyrphus lundbecki													23	10	HRS
Metasyrphus nitens					1								115	50	HRS
Microdon analis						1							175	50	HRS
Microdon devius						1							97	27	HRS
Microdon mutabilis						1							321	86	HRS
Microdon myrmicae													11	11	HRS
Myathropa florea						0.5	0.5						7589	1185	HRS
Myolepta dubia						1							152	58	HRS
Myolepta potens													11	3	HRS
Neoascia geniculata							1						374	170	HRS
Neoascia interrupta					1								229	73	HRS
Neoascia meticulosa					1								982	335	HRS

Neoascia obliqua					1								346	131	HRS
Neoascia podagrica					0.5			0.5					6632	1255	HRS
Neoascia tenur							1						4699	776	HRS
Neocnemodon brevidens													21	15	HRS
Neocnemodon latitarsis					1								73	48	HRS
Neocnemodon pubescens					1								67	40	HRS
Neocnemodon verrucula													13	14	HRS
Neocnemodon vitripennis						0.5	0.5						328	121	HRS
Orthonevra brevicornis					0.5	0.5							295	146	HRS
Orthonevra geniculata					1								221	105	HRS
Orthonevra nobilis						0.5		0.5					1045	407	HRS
Paragus albifrons							0.5	0.5					51	17	HRS/GBIF
Paragus haemorrhous							1						1778	477	HRS
Paragus tibialis							1						55	25	HRS
Parasyrphus annulatus						1							230	122	HRS
Parasyrphus lineola						0.5	0.5						296	128	HRS
Parasyrphus malinellus					1								151	81	HRS
Parasyrphus nigritarsis					1								90	37	HRS
Parasyrphus punctulatus					1								1175	435	HRS
Parasyrphus vittiger						1							452	166	HRS
Parhelophilus consimilis							1						165	51	HRS
Parhelophilus frutetorum						1							826	287	HRS
Parhelophilus versicolor						1							1232	334	HRS
Pelecocera tricincta							1						161	28	HRS
Pipiza austriaca						1							1040	428	HRS
Pipiza bimaculata					1								251	152	HRS
Pipiza fenestrata					1								238	137	HRS
Pipiza lugubris								1					133	86	HRS
Pipiza luteitarsis					1								454	185	HRS
Pipiza noctiluca					1								2221	608	HRS
Pipizella maculipennis													26	25	HRS

Pipizella viduata						1							2169	582	HRS
Pipizella virens						1							435	203	HRS
Platycheirus albimanus					0.5		0.5						17432	1773	HRS
Platycheirus ambiguus				1									638	225	HRS
Platycheirus amplus													9	7	HRS
Platycheirus angustatus							1						2548	861	HRS
Platycheirus aurolateralis													6	6	HRS
Platycheirus clypeatus							1						3839	1016	HRS
Platycheirus discimanus				1									117	69	HRS
Platycheirus europaeus						1							77	45	HRS
Platycheirus fulviventris						1							1267	383	HRS
Platycheirus granditarsus							0.5	0.5					4910	1065	HRS
Platycheirus immarginatus						0.5	0.5						203	98	HRS
Platycheirus manicatus					0.5	0.5							4780	1251	HRS
Platycheirus melanopsis							1						51	18	HRS
Platycheirus nielseni							1						361	152	HRS
Platycheirus occultus							1						393	190	HRS
Platycheirus peltatus								1					1195	808	HRS
Platycheirus perpallidus						1							173	78	HRS
Platycheirus podagratus						1							219	96	HRS
Platycheirus ramsarensis						0.5	0.5						163	89	HRS
Platycheirus rosarum						0.5	0.5						2896	751	HRS
Platycheirus scambus						0.5	0.5						899	399	HRS
Platycheirus scutatus					0.5			0.5					6112	1116	HRS
Platycheirus splendidus					1								56	39	HRS
Platycheirus sticticus					1								77	60	HRS
Platycheirus tarsalis					1								1297	384	HRS
Pocota personata					1								99	42	HRS
Portevinia maculata					1								1298	348	HRS
Psilota anthracina					1								60	29	HRS
Rhingia campestris					1								13214	1673	HRS

Rhingia rostrata								1					358	95	HRS
Riponnensia splendens							0.5	0.5					1465	566	HRS
Scaeva albomaculata													2	2	HRS
Scaeva mecogramma													1	1	HRS
Scaeva pyrastri								1					4467	1090	HRS
Scaeva selenitica							0.5	0.5					528	239	HRS
Sericomyia lappona						1							1322	403	HRS
Sericomyia silentis							0.5	0.5					5160	1024	HRS
Sphaerophoria bankowskae													3	3	HRS
Sphaerophoria batava								1					350	103	HRS
Sphaerophoria fatarum							1						328	140	HRS
Sphaerophoria interrupta							1						1883	682	HRS
Sphaerophoria loewi						1							52	12	HRS/GBIF
Sphaerophoria philanthus							1						921	352	HRS
Sphaerophoria potentillae													6	3	HRS
Sphaerophoria rueppellii							1						577	190	HRS
Sphaerophoria scripta								1					8042	1053	HRS
Sphaerophoria taeniata								1					404	138	HRS
Sphaerophoria virgata						0.5	0.5						75	45	HRS
Sphegina clunipes						1							1892	659	HRS
Sphegina elegans						1							829	329	HRS
Sphegina sibirica						1							70	43	HRS
Sphegina verecunda						1							349	171	HRS
Syritta pipiens							0.5	0.5					17086	1702	HRS
Syrphus ribesii							0.5	0.5					13327	1577	HRS
Syrphus torvus							1						3351	830	HRS
Syrphus vitripennis								1					6974	1264	HRS
Trichopsomyia flavitarsis						1							795	331	HRS
Triglyphus primus								1					194	80	HRS
Tropidia scita						1							1996	385	HRS
Volucella bombylans						1							5295	1215	HRS

Volucella inanis								1					1321	242	HRS
Volucella inflata						1							891	262	HRS
Volucella pellucens							1						7837	1317	HRS
Volucella zonaria								1					1249	177	HRS
Xanthandrus comtus								1					399	171	HRS
Xanthogramma citrofasciatum					1								513	224	HRS
Xanthogramma pedissequum						0.5	0.5						2063	458	HRS
Xylota abiens						1							267	95	HRS
Xylota florum							1						423	167	HRS
Xylota jakutorum						1							715	212	HRS
Xylota segnis						1							9049	1376	HRS
Xylota sylvarum							1						2926	721	HRS
Xylota tarda							1						202	84	HRS
Xylota xanthocnema						0.5	0.5						244	106	HRS
Totals	**0**	**0**	**0**	**9.5**	**69**	**65**	**65.5**	**51.5**	**0.5**	**0**	**0**	**0**	**492739**	**97773**	

560

561

Appendix S4 - Peak number of butterfly observations per species, per calendar month (J = January etc.) calculated from the United Kingdom Butterfly Monitoring Scheme and Global Biodiversity Information Facility databases. Records from all years were binned per month for all species with ≥50 total observations (100%; 64 out of 64 species). When the difference between the two months with the greatest number of insect observations was <10%, the peak abundance of a species was considered to be spread across both months (e.g. *Aglais urticae* observations are equal and maximal in July and August, resulting in each month being 'scored' 0.5 for this species). When the difference was >10% the peak abundance of a species was considered to peak in only one month (e.g.. *Boloria selene* peak observations are in June, resulting in this month being 'scored' 1 for this species).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Records	Hectads	Source
Aglais io								1					6017	2490	UKBMS
Aglais urticae							0.5	0.5					6389	2607	UKBMS
Anthocharis cardamines					1								2765	2240	UKBMS
Apatura iris							1						252	213	UKBMS
Aphantopus hyperantus							1						2698	2262	UKBMS
Aporia crataegi							1						153	0	GBIF
Argynnis adippe							1						93	0	GBIF
Argynnis aglaja							1						2444	1223	UKBMS
Argynnis paphia							1						2223	775	UKBMS
Aricia agestis								1					3743	122	UKBMS
Aricia artaxerxes							1						1261	122	UKBMS
Boloria euphrosyne					1								1477	190	UKBMS
Boloria selene						1							2013	769	UKBMS
Callophrys rubi					1								2260	1107	UKBMS
Carterocephalus palaemon						1							195	40	UKBMS
Celastrina argiolus								1					3843	1431	UKBMS
Coenonympha pamphilus							0.5	0.5					5281	2102	UKBMS
Coenonympha tullia							1						528	338	UKBMS
Colias croceus								1					1491	996	UKBMS
Cupido minimus						1							2077	279	UKBMS
Cyaniris semiargus						0.5	0.5						11014	0	GBIF
Epargyreus clarus								1					1008	42	UKBMS

Erebia aethiops								1					911	378	UKBMS
Erebia epiphron							1						193	39	UKBMS
Erynnis tages					0.5	0.5							2239	643	UKBMS
Euphydryas aurinia						1							894	246	UKBMS
Fabriciana adippe							1						1258	21	UKBMS
Gonepteryx rhamni					0.5			0.5					5948	1346	UKBMS
Hamearis lucina					1								857	84	UKBMS
Hipparchia semele								1					2544	542	UKBMS
Lasiommata megera								1					4013	1089	UKBMS
Leptidea juvernica						1							263	35	UKBMS
Leptidea sinapis						1							1345	48	UKBMS
Limenitis camilla							1						1551	427	UKBMS
Lycaena phlaeas								0.5	0.5				5316	2081	UKBMS
Lycaena dispar							1						238	0	GBIF
Maniola jurtina							0.5	0.5					4445	2525	UKBMS
Melanargia galathea							1						2322	798	UKBMS
Melitaea athalia							1						738	13	UKBMS
Melitaea cinxia						1							184	17	UKBMS
Neozephyrus quercus							0.5	0.5					1763	934	UKBMS
Nymphalis polychloros							1						466	0	GBIF
Ochlodes sylvanus							1						3113	1553	UKBMS
Papilio machaon						1							409	65	UKBMS
Parage aegeria							0.5	0.5					6379	2085	UKBMS
Phengaris arion						1							54	6	UKBMS
Pieris brassicae							0.5	0.5					5926	2239	UKBMS
Pieris napi							0.5	0.5					6186	2697	UKBMS
Pieris rapae							0.5	0.5					6241	2153	UKBMS
Plebejus argus							1						1496	105	UKBMS
Polygonia c-album							0.5	0.5					5253	1718	UKBMS
Polyommatus bellargus						1							2385	125	UKBMS
Polyommatus coridon								1					2242	249	UKBMS

Polyommatus icarus							0.5	0.5					5228	2291	UKBMS
Pyrgus malvae						1							1874	340	UKBMS
Pyronia tithonus							0.5	0.5					3165	1458	UKBMS
Satyrium pruni						1							155	25	UKBMS
Satyrium w-album							1						700	641	UKBMS
Thecla betulae								1					436	155	UKBMS
Thymelicus acteon								0.5	0.5				576	14	UKBMS
Thymelicus lineola							1						1660	725	UKBMS
Thymelicus sylvestris							1						3052	1483	UKBMS
Vanessa atalanta								0.5	0.5				5365	2436	UKBMS
Vanessa cardui								1					3551	1886	UKBMS
Totals	**0**	**0**	**0**	**0**	**5**	**13**	**26.5**	**18.5**	**1**	**0**	**0**	**0**	**162159**	**55063**	

562

563

Appendix S5 - Peak number of Regionally Extinct (RE), Critically Endangered (CR) and Endangered (EN) pollinator species, per calendar month (J = January etc.) calculated from the Bees, Wasps & Ants Recording Society (BWARS), the United Kingdom Butterfly Monitoring Scheme (UKBMS), the Hoverfly Recording Society (HRS) and the Global Biodiversity Information Facility (GBIF) databases. The status of butterfly species was taken from Fox et al., (2010), hoverfly species from Ball & Morris (2015), extinct bees from Falk (2015), extinct wasps from Ollerton et al., (2014) and endangered bees and wasps from Falk (1991).

When the difference between the two months with the greatest number of insect observations was <10%, the peak abundance of a species was considered to be spread across both months (e.g. *Cyaniris semiargus* observations are equal and maximal in June and July, resulting in each month being 'scored' 0.5 for this species). When the difference was >10% the peak abundance of a species was consider to peak in only one month (e.g. *Maculinea arion* peak observations are in June, resulting in this month being 'scored' 1 for this species).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Records	Status	Source
Butterflies															
Aporia crataegi							1						153	RE	GBIF
Cyaniris semiargus						0.5	0.5						11014	RE	GBIF
Lycaena dispar							1						238	RE	GBIF
Maculinea arion						1							54	RE	UKBMS
Nymphalis polychloros							1						466	RE	GBIF
Argynnis adippe							1						93	CE	GBIF
Boloria euphrosyne					1								1477	EN	UKBMS
Carterocephalus palaemon						1							195	EN	UKBMS
Hamearis lucina					1								857	EN	UKBMS
Leptidea sinapis						1							1345	EN	UKBMS
Melitaea athalia							1						738	EN	UKBMS
Melitaea cinxia						1							184	EN	UKBMS
Satyrium pruni						1							155	EN	UKBMS
Satyrium w-album							1						700	EN	UKBMS

Hoverflies															
Blera fallax						1							380	CE	HRS/GBIF
Eristalis cryptarum							0.5	0.5					85	CE	HRS
Paragus albifrons							0.5	0.5					51	CE	HRS/GBIF
Myolepta potens						1							11	CE	HRS
Chrysotoxum octomaculatum						1							56	EN	HRS
Chrysotoxum vernale					1								64	EN	HRS
Hammerschmidtia ferruginea						1							259	EN	HRS/GBIF
Bees															
Andrena floricola				0.5			0.5						47	RE	GBIF
Andrena lathyri					1								950	RE	BWARS/GBIF
Andrena lepida							1						3	RE	BWARS
Andrena nana					0.5		0.5						52	RE	BWARS/GBIF
Andrena nanula							1						80	RE	GBIF
Andrena polita							1						17	RE	BWARS/GBIF
Andrena tridenta								1					7	RE	BWARS/GBIF
Bombus cullumanus								1					53	RE	BWARS/GBIF
Bombus pomorum								1					94	RE	BWARS/GBIF
Bombus subterraneus								1					226	RE	BWARS
Coelioxys afra							1						44	RE	GBIF
Duforea halictula							1						281	RE	BWARS/GBIF
Dufourea minuta							1						61	RE	BWARS/GBIF
Eucera nigrescens					1								157	RE	BWARS/GBIF
Halictus maculatus							1						315	RE	GBIF
Halictus subauratus						0.5	0.5						123	RE	GBIF
Hoplitis leucomelana							1						277	RE	GBIF
Hylaeus punctulatissimus						1							102	RE	GBIF
Lasioglossum laeve							1						17	RE	GBIF
Megachile ericetorum						0.5	0.5						172	RE	GBIF
Megachile lapponica								1					254	RE	GBIF

Megachile parietina					1								16	RE	GBIF
Melecta luctuosa					1								74	RE	GBIF
Nomada errans							1						27	RE	BWARS/GBIF
Rophites quinquespinosus							1						44	RE	GBIF
Andrena ferox					1								84	EN	BWARS
Andrena floricola				0.5			0.5						47	EN	GBIF
Andrena gravida				1									52	EN	BWARS
Andrena lathyri					1								950	EN	BWARS/GBIF
Andrena lepida							1						3	EN	BWARS
Andrena nana					0.5		0.5						52	EN	BWARS/GBIF
Andrena polita							1						17	EN	BWARS/GBIF
Andrena tridenta								1					7	EN	BWARS/GBIF
Andrena vaga				1									2275	EN	BWARS/GBIF
Anthophora retusa					1								126	EN	BWARS
Bombus cullumanus								1					53	EN	BWARS/GBIF
Dufourea minuta							1						61	EN	BWARS/GBIF
Eucera nigrescens					1								157	EN	BWARS/GBIF
Halictus eurygnathus								1					51	EN	BWARS
Halictus maculatus							1						315	EN	GBIF
Lasioglossum sexnotatum						1							418	EN	BWRAS
Melecta luctuosa					1								85	EN	BWARS/GBIF
Melitta dimidiata							1						748	EN	BWARS
Osmia xanthomelana					0.5	0.5							226	EN	BWARS/GBIF
Nomada armata							1						66	EN	BWARS
Nomada errans							1						27	EN	BWARS/GBIF
Nomada guttulata					1								115	EN	BWARS/GBIF
Nomada sexfasciata					1								96	EN	BWARS/GBIF
Nomada ferruginata				1									69	EN	BWARS
Aculeate Wasps															
Ancistrocerus antilope						0.5	0.5						47	RE	BWARS/GBIF

Ancistrocerus quadratus							1						38	RE	GBIF
Arachnospila rufa							1						365	RE	BWARS/GBIF
Chrysis longula							1						112	RE	BWARS/GBIF
Chrysis pseudobrevitarsis						0.5	0.5						52	RE	BWARS/GBIF
Lestica clypeata						0.5	0.5						286	RE	GBIF
Mellinus crabroneus							1						91	RE	BWARS/GBIF
Odynerus reniformis						1							95	RE	BWARS/GBIF
Philoctetes truncatus						0.5	0.5						6	RE	BWARS/GBIF
Psen ater								1					19	RE	GBIF
Arachnospila rufa							1						365	EN	BWARS/GBIF
Cerceris quadricincta							0.5	0.5					73	EN	BWARS
Ceropales variegata								1					72	EN	BWARS/GBIF
Chrysis fulgida						1							54	EN	BWARS
Crossocerus vagabundus							1						305	EN	BWARS
Evagetes pectinipes							1						365	EN	BWARS/GBIF
Homonotus sanguinolentus							1						1193	EN	BWARS
Mellinus crabroneus							1						91	EN	BWARS/GBIF
Odynerus simillimus							1						75	EN	BWARS
Omalus puncticollis							1						69	EN	BWARS
Philoctetes truncatus						0.5	0.5						6	EN	BWARS/GBIF
Pseudepipona herrichii							1						145	EN	BWARS

References

Ball, S., & Morris, R. (2015) *Britain's Hoverflies: A Field Guide*. Princeton University Press, New Jersey, U.S.A.

Falk, S. (1991) *A review of the scarce and threatened bees, wasps and ants of Great Britain* (No. 35). Nature Conservancy Council for England, Peterbourgh, U.K.

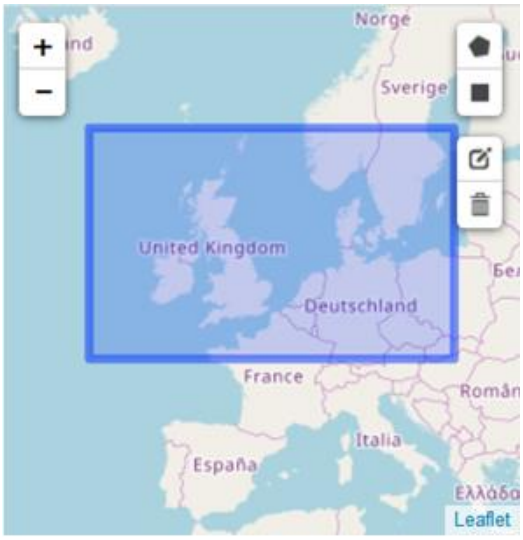
Falk, S.J. (2016) *Field guide to the bees of Great Britain and Ireland*. British Wildlife Publishing, Totnes, U.K.

Fox, R., Warren, M.S., Brereton, T.M., Roy, D.B. and Robinson, A. (2010) A new Red List of British butterflies. *Insect Conservation and Diversity*, 4, 159-172.

Ollerton, J., Erenler, H., Edwards, M. and Crockett, R. (2014) Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes. *Science*, 346, 1360-1362.

564

565 **Appendix S6**



566

567 **Figure A** - Geographical area used to generate The Global Biodiversity Information Facility
568 (GBIF) records used in phenological calculations

569

570 **Table A** - Proportion of GBIF records used per country

Country	Proportions
Sweden	0.413
Germany	0.311
Netherlands	0.077
Norway	0.076
Belgium	0.033
Czech Republic	0.021
Luxembourg	0.021
France	0.018
Austria	0.017
Ireland	0.007
Poland	0.003
Åland Islands	0.001
Denmark	0.001
Finland	0.001

571